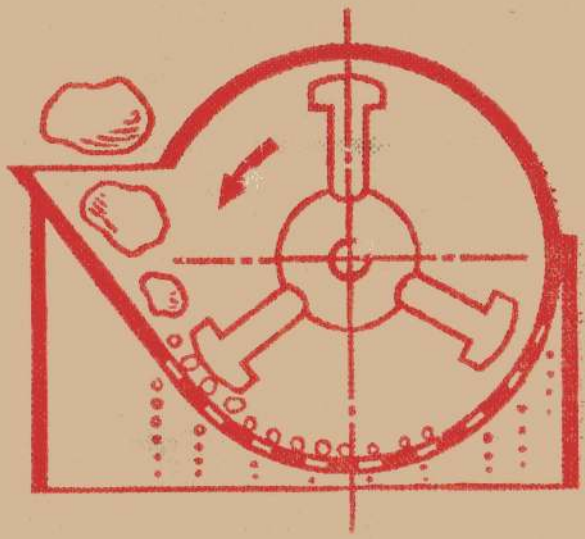
N. JUNKOVSKY

CONVEYING CRUSHING WASHING AND SCREENING MACHINERY



И. Джунковский

ТРАНСПОРТИРУЮЩИЕ, ДРОБИЛЬНЫЕ, МОЕЧНО-СОРТИРОВОЧНЫЕ МАШИНЫ

ИЗДАТЕЛЬСТВО «ВЫСШАЯ ШКОЛА» • МОСКВА

На английском языке

N. Junkovsky

CONVEYING, CRUSHING, WASHING and SCREENING MACHINERY

Translated from the Russian
by
David Sobolev

MIR PUBLISHERS ● MOSCOW 1966

UDC 621.92:621.928(075.3)=20

Revised from the 1963 Russian edition

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CHAPTER ONE

MATERIALS OF CONSTRUCTION

1. Metals and Alloys

Most machine elements are made of metals or alloys. Metals may be ferrous or nonferrous. *Ferrous* metals include iron and its alloys, cast iron and steel; *nonferrous* metals are copper, zinc, lead, tin, aluminium, etc., and their alloys, viz., bronze, brass, etc.

The elements of contractor's machinery are made chiefly of iron and steel.

Machine elements operate under a wide range of service conditions: some work under static (constant) load, others under dynamic (impact) load; some of them can be subject to tension, compression, bending, twisting, or several of these at a time, for instance, bending and twisting stresses. There are machine elements that work under conditions of heavy friction, whereas others are strongly attacked by corrosion (rusting). Therefore, the metals employed for making machine elements have to meet different requirements with regard to strength and resistance to wear. Hence, to choose the right metal for any particular part, we must be familiar with their properties.

The science and art dealing with the extraction of metals and their adaptation to the uses for which they are needed is called *metallurgy*. A foundation for metallurgy in Russia was laid by M. V. Lomonosov who in 1763 wrote the first book on metallurgy in Russian, called *First Elements of Metallurgy or Ore Craft*. A great deal was done for the further development of metallurgy by Soviet scientists.

The branch of science which studies the structure and physical properties of metals and alloys is called *physical metallurgy*. A scientific foundation for physical metallurgy was built up by the Russian scientist D. K. Chernov. To

date the structure and physical properties of metals and alloys, as well as the effects of the constituent elements on their properties and machinability have been studied in great detail.

The structure of a metal is its build as observed through a microscope or a magnifying glass. The crystalline structure visible through a microscope at high magnification is called *microstructure*, while that discernible by the naked eye or at low magnification is known as *macrostructure*.

PROPERTIES OF METALS AND ALLOYS

We must distinguish between the physical, chemical and mechanical properties of metals and alloys.

Physical Properties. The principal physical properties of metals and alloys are their density, melting point, thermal conductivity, electrical conductivity and magnetic properties.

Density (mass per unit volume) is the ratio of a mass at rest (kg) to its volume (m^3). Density is measured in kg/m^3. Where specific gravity is involved, it is found as the product of the density by the true acceleration due to gravity at the point of measurement. The dimension of specific gravity is N/m^3.

Melting point is the temperature at which a material passes from the solid into the liquid state.

Thermal conductivity is the ability of a material to transport heat from its hotter to its cooler parts without these parts moving. The thermal conductivity of a material is the amount of heat (kcal) flowing per unit time (one hour) through a body 1 m^2 in cross section and 1 m in length under a temperature difference of 1 degree.

Electrical conductivity is the ability of a material to conduct electric current. Conductivity is the inverse of resistivity. Resistivity is the resistance which 1 cm^3 of the material offers to the passage of electricity. It is measured in ohm$\times$cm.

Chemical Properties. The chief chemical properties of metals and alloys are their ability to resist corrosion, oxidation and attack by acids and alkalis. Resistance to oxidation at high temperatures is called *heat resistance*. Heat-resistant

metals and alloys are employed to make parts that operate at high temperatures.

Mechanical Properties. The main mechanical properties of metals and alloys are: strength, elasticity, plasticity, hardness, resilience, etc.

Strength is the ability of a metal to withstand stress without breaking.

When a stress is applied in one direction, the material is deformed not only in that direction, but in others as well. For example, when a tensile stress is applied to a metal rod it is elongated, and its cross-sectional area decreases at the same time.

Elasticity is the power of a metal to resist distortion and to assume its original shape after having been distorted.

Plasticity is the opposite of elasticity. A plastic body once distorted will not regain its original shape.

Hardness is the power of a material to resist penetration by a harder body.

Strength, elasticity, plasticity and hardness are expressed in kg/mm^2 or kg/cm^2.

Resilience is the resistance of a material to impact and is expressed in kg/cm^2.

IRON AND STEEL

Properties of Cast Iron. Cast iron is an alloy of iron and carbon, containing more than 2 per cent of carbon. Pure iron-carbon alloys are hardly ever obtained in practice. Ordinarily iron contains a number of other elements as impurities besides carbon. These usually are silicon, manganese, phosphorus and sulphur.

Depending on its grade, cast iron may contain 2 to 4.5 per cent carbon, 0.5 to 4.5 per cent silicon, 0.5 to 1 per cent manganese, 0.1 to 1.2 per cent phosphorus; the sulphur content must not exceed 0.08 to 0.15 per cent.

Cast iron is brittle and unmalleable.

Impurities and Their Effect on the Structure and Properties of Cast Iron. The elements contained in cast iron affect its structure and properties differently.

Carbon may be present in cast iron either in the free state as graphite dispersed among the iron grains or as a chem-

ical compound with the iron called cementite or carbide. Increasing the carbon content lowers the melting point of cast iron, increases its fluidity, promotes the formation of graphite in the iron, improves its ability to fill the mould on casting, reduces "shrinkage" (decrease in size of the casting after solidification), i.e., improves its casting properties.

Silicon affects the structure and properties of cast iron in the same way as carbon.

In contrast to silicon, *manganese* prevents the formation of graphite and promotes the formation of cementite, raises the hardness of the iron and impairs its castability.

Phosphorus improves the casting properties of iron, but lowers its strength, making it more brittle.

Sulphur is a harmful impurity; it passes into the iron from the fuel and ores. Sulphur impairs the casting properties of iron due to the entrapment of gases in the liquid metal and formation of blowholes in the casting. Sulphur makes cast iron hard and brittle.

Materials for Smelting Iron. The materials needed to smelt iron are iron ores, fuel and flux.

Ore is mined from the earth's crust and is a rock consisting of iron compounds and gangue. The iron compounds contained in ores may be oxides, or compounds of iron and oxygen; spars, or ferrous carbonates; pyrites, or compounds of iron and sulphur. The gangue contains silica, alumina, calcium oxide, manganese oxide, phosphoric oxide, etc.

The principal types of iron ores are black iron ores (magnetites), red iron ores (hematites), brown iron ores (limonites) and carbonate iron ores (siderites).

The *fuel* for pig-iron smelting is usually coke; and—although more seldom—charcoal. Coke is a light-weight, porous fuel obtained by heating certain grades of coal without access of air.

Fluxes are the materials which promote fusion of the gangue and the ash of the fuel into a waste product called *slag*. The most commonly used flux is limestone; in some cases siliceous hearth cinders are employed.

The *charge* is the name given to the mixture of ore, fuel and flux in the necessary proportions for smelting the iron. The ore and flux are mixed before being charged (or loaded)

into the blast furnace, the mixture being referred to as an *ore charge.*

The fuel is added in separate portions called *fuel charges.*

Pig iron is smelted in blast furnaces. The liquid iron is tapped from the blast furnace and cast into pigs. The capacity of a blast furnace may be as high as 2,000 tons per day.

Classification of Pig Iron. Pig iron smelted in blast furnaces falls into conversion (or steel-making), special (ferroalloy) and foundry irons.

Conversion and *special irons* are used for steel manufacture. Depending on the kind of fuel added to the blast furnace, conversion iron may be coke iron or charcoal iron, and depending on the method of smelting and conversion into steel it is divided into open-hearth, Bessemer and Thomas or basic.

Foundry iron is used for casting various articles and machine elements at foundries.

Foundry iron may be white or gray.

White iron has a white fracture owing to the carbon in it being contained as a chemical compound with the iron.

White iron is very hard, brittle and wear-resistant. Its casting properties are lower than those of gray iron. White iron castings are difficult to machine. White iron is used rarely in foundry work for mechanical engineering; the only parts cast from it are those in which high wear resistance is required. White iron is mostly converted into steel.

Gray iron contains carbon as graphite dispersed among the iron grains making the fracture of this iron gray. Gray iron is soft and brittle and possesses good casting properties. Gray iron castings are readily machinable.

Gray iron castings fall into three groups: low-strength, medium-strength and high-strength. Table 1 lists the grades and fields of application of castings made of low- and medium-strength gray iron, which are the most commonly used in mechanical engineering. The grades, except for СЧ-00, contain four digits, the first two indicating the tensile strength, and the second two, the bending strength.

High-strength iron is obtained by adding 0.3-1.2 per cent magnesium in the ladle; the grades of this iron are ВЧ50-1.5; ВЧ60-2, etc.

Table 1

Gray Iron (to GOST 1412-54) *

Grade	Mechanical strength			Applications
	Brinell hardness, H_B	Tensile strength, kg/mm²	Bending strength, kg/mm²	
СЧ-00	Not tested			Parts subject to small loads, such as pillars, covers, pads, counterweights, etc.
СЧ15-32	163-229	15	32	Heavy castings, such as frames, flywheels, gears, etc.
СЧ18-36	170-229	18	36	Gears, pulleys, etc.
СЧ21-40	170-241	21	40	Diesel heads, cylinders and pistons, pump and hydraulic press frames, valves, valve gear, bed frames, etc.
СЧ28-48	170-241	28	48	Odd-shaped castings: high-speed engine frames, cylinder blanks with walls from 10 to 20 mm thick.
СЧ32-52	187-255	32	52	Odd-shaped castings with mating walls of different thicknesses (minimum wall thickness 10 mm); cylinders, covers, gears.

* GOST (ГОСТ) stands for "U.S.S.R. State Standard".

Malleable iron castings are produced by subjecting white iron castings to annealing at 950-1,000°C and holding at 720-730°C.

Malleable iron is ductile, has a high tensile strength and resists impact loads and corrosion well.

Depending on the method of annealing, malleable iron may be black heart and white heart. The former results when white iron castings are annealed in sand-packed boxes, and the latter in iron ore-packed boxes.

Iron castings are made by melting pig iron in cupolas, transferring the liquid iron in ladles and pouring it into moulds. When the iron has frozen, the castings are knocked out of the moulds, fettled and cleaned.

The chemical composition and nature of castings depend on the chemical and quantitative composition of the metal charge.

Fettling involves removal of excess metal (risers and gates) by chipping or cutting. Castings are cleaned from adhering moulding sand by sand blast or a high-pressure water jet; small castings are cleaned by tumbling in revolving barrels.

Properties of Steel. Steel is a malleable alloy of iron and carbon. The amount of carbon does not exceed 2 per cent. Besides carbon, steel contains the ordinary impurities: manganese, silicon, phosphorus and sulphur, but their proportion is smaller than in pig or cast iron.

Depending on the grade of steel, it may contain manganese, 0.3 to 0.8 per cent; silicon, 0.2 to 0.4 per cent; phosphorus, not over 0.01-0.09 per cent, and sulphur not over 0.01-0.07 per cent.

Steel is stronger than cast iron. Raised to a light-red heat, steel can be forged, white-hot steel can be welded. The softer the steel the more readily it can be forged and welded.

The impurities contained in steel affect its structure and properties.

Carbon is the most important element on which the structure and properties of steel depend. It increases the strength, hardness and brittleness of steel. The method of of machining and service life of steel articles depend largely on the carbon content.

Manganese increases the hardness and strength of steel.

Silicon has much the same effect as manganese, and increases rigidity and elasticity as well.

Phosphorus, when present in increased quantities, makes steel brittle in the cold state, this property being known as cold-shortness.

Increased amounts of *sulphur* make steel brittle when hot; this property is called red-shortness.

Steel is produced from conversion iron in converters and from conversion iron and steel scrap in open-hearth or electric furnaces.

Classification of Steels. Steels are classified according to chemical composition, quality and application.

According to *chemical composition* we distinguish carbon steels and alloy steels.

Carbon steels fall into low-carbon steel containing under 0.25 per cent carbon, medium-carbon steel with 0.3 to 0.6 per cent carbon, and high-carbon steel with more than 0.6 per cent carbon.

Carbon steels may contain up to 0.8 per cent manganese, up to 0.37 per cent silicon, up to 0.07 per cent sulphur and up to 0.09 per cent phosphorus.

Alloy steels contain additions (alloying elements) which change their properties. The most important additions are chromium, nickel, molybdenum, tungsten, vanadium, titanium, manganese and silicon.

Alloying elements have different effects on the properties of steel.

Chromium is a widely used alloying addition. Steel containing chromium is called chrome steel. Chrome steel is noted for its high strength, hardness, resistance to wear and corrosion.

Nickel raises the strength and ductility of steel. Steel containing nickel is known as nickel steel.

If both chromium and nickel are added to steel the result is nickel-chromium steel noted for its very high hardness and ductility.

Molybdenum raises the strength of steel at high temperatures and eliminates brittleness.

Tungsten makes steel hard, red hard and eliminates brittleness.

Vanadium imparts hardness to steel, which it retains even at high temperatures.

Titanium increases ductility and resistance to corrosion on heating.

Manganese is a widely used alloying element. Steel containing an increased quantity of manganese is known as manganese steel. Manganese steel containing 1 per cent manganese goes to make rails, shafts, gears, etc.; manganese steel with 12 to 14 per cent manganese is wear-resistant and is employed for the manufacture of members subject to shocks and high wear, such as the crusher wear plates, power shovel dippers, etc.

Silicon is often used as an alloying addition. Steel containing a large amount of silicon is called silicon steel. Silicon content up to 1 per cent increases the strength of the steel while retaining its ductility; such steels are used to make springs. Silicon raises the heat resistance of steel.

Depending on the total content of alloying elements, there are: low-alloy steels (less than 3 per cent of alloying additions), medium-alloy steels (up to 5.5 per cent) and high-alloy steels (over 5.5 per cent).

According to the U.S.S.R. State Standard, the additions in alloy steels are indicated in their grade index by the following letters of the Russian alphabet: Х, chromium; Н, nickel; М, molybdenum; В, tungsten; Ф, vanadium; Т, titanium; К, cobalt; А, aluminium; Д, copper; П, phosphorus; Г, manganese; and С, silicon. The figures preceding these letters show the carbon content, and those following, the content of the alloying element in question. Further, some alloy steels are classed into special groups, identified by letters preceding the grade index: Ш, ball-bearing steel; Р, high-speed steel; Ж, chromium stainless steel; Я, nickel-chromium stainless steel.

According to *quality*, steels fall into three classes: I—ordinary-strength steel; II—high-strength steel; III—superhigh quality strength steel.

According to *application* steels fall into three classes: I, structural steel; II, tool steel; III, special steel.

I. *Structural steels* include machinery or machine tools.

Structural steels are used for civil engineering purposes. They are of the ordinary-strength carbon class and usually require no heat treatment.

Machinery steels are carbon and alloy high- and superhigh-strength steels. Most of these steels require heat treatment. They are used for making shafts, axles, gears and other machine parts. The main consideration is their mechanical properties.

The following grades of structural alloy steels are employed for the manufacture of contractor's machinery: 20X, for gears, pump plungers, piston pins, etc.; 40X and 40XH, for gears, crankshafts and other heavy-duty members; 12XH2A, for gears, shafts and other parts operating at high speeds and subject to impact loads.

This class includes special-purpose steels for making certain machine elements, such as flat and helical springs, corrosion-resistant members. Examples are 45Г2 steel for locomotive, railway car and tram axles; Б56 steel, for rails; 65Г, 55ГС, 50ХГ steels for springs, etc.

II. *Tool steel* is classified further according to chemical composition and use.

With regard to chemical composition tool steels may be carbon or alloy steels.

III. *Special steels* are alloy steels and are employed mainly in electrical engineering and instrument making. They include steels made into articles whose dimensions must not change with temperature; magnetic and nonmagnetic steels, etc.

Steel Articles. Steel articles can be produced by rolling, forging and casting.

Plate, sheet, structural shapes, sections, seamless piping and tubing are fabricated by rolling. Odd shapes are produced by forging and pressing. Many machine parts are castings.

Structural shapes and sheet are rolled from steel ingots in rolling mills. The process of rolling consists in passing preheated ingots between two sets of rolls. The rolls rotate in opposite directions, and the opening between them is set smaller than the thickness of the ingot (Fig. 1).

Depending on the section to be manufactured, the rolls may be plain or grooved. For plate, sheet and strip rolling,

the rolls are plain, and rolling mills making such products are called plate, sheet or strip mills. Grooved rolls (Fig. 2)

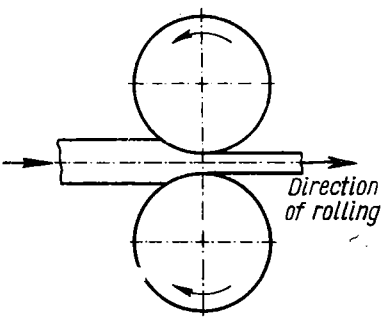


Fig. 1. Schematic representation of rolling

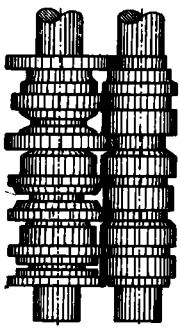


Fig. 2. Grooved rolls for rolling T-beams

are used for rolling the following sections and shapes (Fig. 3): rounds *1*, squares *2*, flat bars *3*, angles *4*, tees *5*, I- and H-beams *6*, channels *7*, rails *8*, zees *9*, etc. Depending on the

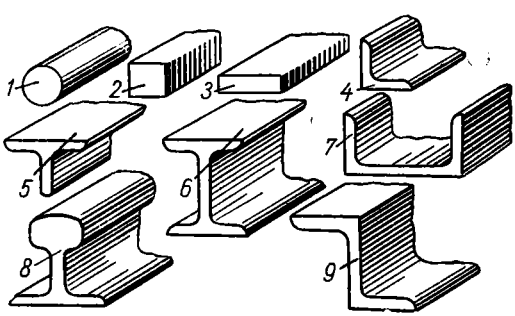


Fig. 3. Shapes of rolled steel:
1—round, *2*—square, *3*—flat bar, *4*—angle, *5*—tee, *6*—H-beam, *7*—channel, *8*—rail, *9*—zee

shape of section produced, there may be bar mills, shape mills, rail mills, etc.

Seamless steel pipes and tubing are made by rolling in special pipe mills.

Forgings are used to make machine parts (shafts, gear blanks, levers, rods, bolts, etc.). The weight of a forging may be as high as 200 tons. They can be made by smith forging (drop forging), and press forging.

Before forging the steel is heated in reheating furnaces, and small-size sections in forges.

Forging may employ dies, hammers, or presses.

Hammers operated by special motor-driven mechanisms are called machine or power hammers. These include helve hammers, spring hammers and others with a falling tup weighing 60 kg, as well as pneumatic hammers actuated by compressed air; the tup of these hammers weighs up to 1 ton. Steam and air hammers are operated by steam or compressed air and have a tup which weighs up to 5 tons.

Power presses develop a force up to 6,000 tons. Hydraulic presses and steam-hydraulic presses develop forces up to 15,000 tons or more.

Steel castings are used in mechanical engineering where shaped parts of high strength and ductility are required, such as gears, pulleys, rollers, frames, crusher wear plates and jaws, power shovel dippers, etc. Castings are made of carbon or alloy steels. After cleanings, steel castings are subjected to annealing.

Table 2 lists the grades and applications of steel castings in the manufacture of contractor's machinery.

The figures in the grade indexes indicate the carbon content in "points" (hundredths of one per cent).

Rolled, forged or cast machine parts such as shafts, gears, screws, etc., are then machined to give them regular geometrical shape, precise dimensions and a smooth (clean) finish.

Heat Treatment of Metals and Alloys. Heat treatment is employed to change the structure of a metal or an alloy, i.e., to give it the required properties (strength, hardness, wear resistance, etc.).

The heating is done in heat-treating furnaces. Of late induction heating by high-frequency currents has come into use for hardening.

The main heat-treating operations are: annealing, normalizing, hardening and tempering.

Table 2

Carbon Steel Castings (GOST 977-58)

Grade of steel	Brinell hardness, H_B	Field of application
15JI	110-120	Parts not subject to high loads, and to be case-hardened: frames, cylinder heads, car wheels, cams, rollers, gears, etc.
25JI	120-125	Cylinders, levers, spiders, flywheels, pulleys, pistons, rollers, cylinder heads, frames and other parts subject to instantaneous loads.
35JI	159-179	Parts subject to wear and requiring high strength: gears, worms, claw clutches, spiders, cylinders, etc.
45JI	163-197	Critical parts working under friction.
55JI	196-225	Parts working under friction at high loads: gears, runners, wheels, etc.

Annealing consists in heating the part to a definite temperature, holding it at that temperature and cooling it slowly in the furnace.

There are full annealing and process annealing.

Full annealing involves heating to a temperature above the critical point, holding at that temperature, and subsequent cooling in the furnace.

Process annealing calls for heating to 600-650°C and is used for relieving internal stresses caused by cold work.

Normalizing means heating the alloy to a definite temperature, holding it at that temperature and cooling in still air. Normalizing involves faster cooling than full or process annealing. Normalizing removes internal strains in castings and forgings, makes them tougher, improves their mechanical characteristics and lowers their hardness, making them easier to machine.

Hardening consists in heating the alloy to a definite temperature and quenching it quickly by plunging it into a liquid. The most frequently used liquids are water, a 5-10 per cent solution of sodium hydroxide, and mineral oil.

Hardening increases the hardness, strength and brittleness of steels.

Carbon, manganese, chromium and chromium-nickel steels containing down to 0.25 per cent carbon are heated to 900°C for hardening. Steel containing 0.56-0.9 per cent carbon is heated to 820°C. Steel containing less than 0.25 per cent carbon does not harden.

Tempering of fully hardened steel is used to relieve quenching stresses and lower its brittleness. For this, hardened steel is heated slowly to a suitable temperature, held at that temperature, and allowed to cool at a definite rate.

The higher the tempering temperature, the greater its ductility and the lower its hardness. If heated above 700°C steel loses the properties it has acquired through hardening.

Tempering may be low, medium and high.

In *low tempering* hardened high-carbon or alloy steel is heated to 150-200°C; this does not lower the hardness of the steel, but only relieves internal stresses. Low tempering is used in the manufacture of cutting tools, gears and other articles requiring high hardness.

Medium tempering is accomplished by heating hardened medium-carbon and alloy steel to 300-450°C and results in high strength and elasticity. Medium tempering is employed when making flat and helical springs and other machine parts operating under impact loads.

High tempering is achieved by heating hardened medium-carbon or alloy high-speed steel to 500-650°C; in this case the tempered article acquires very high toughness. High tempering is applied when making special bolts, automobile axles and other critical parts.

The tempering temperature can be determined approximately by temper colours on the surface of the article being treated. Pale yellow corresponds to a temperature of 220°C, straw yellow to 230, golden yellow to 240, brown to 255, brown-red to 265, purple to 277, bright blue to 285, pale blue to 300, and dark blue to 315°C.

The rate of cooling in tempering carbon steel is immaterial, but alloy steel must be cooled rapidly to avoid embrittlement.

Surface Impregnation. This is a version of heat treatment wherein the steel is heated and simultaneously subjected to

chemical processes which take place under special conditions.

One of the processes that come under this heading is carburizing. It is applied when a part should have a hard surface and a soft core. For this purpose, the part is made of mild steel low in carbon and therefore not amenable to hardening. The part is then packed in a steel box with a substance high in carbon (for example, a mixture of 40 per cent soda and 60 per cent fine charcoal), the box is covered, sealed with clay and heated in a furnace for 10-15 hr at 900-940°C.

When heated, the outer layer of the part absorbs carbon from the surrounding charcoal, while the soda serves to accelerate the process. Thus, the outer layer of the part becomes saturated with carbon to a depth of 1-1.5 mm, being converted into a steel with a high carbon content, i.e., into hard steel.

Carburizing also changes the chemical composition of the outer layer of the part.

After hardening, the article acquires a hard surface layer while retaining a soft ductile core.

NONFERROUS METALS

The following nonferrous metals are most frequently employed in mechanical engineering: copper, zinc, lead, tin, and aluminium.

Copper is a soft reddish metal which can be readily shaped cold or hot by rolling, forging, and pressing. Copper resists corrosion well.

Zinc is a soft grayish white metal with a strong metallic lustre, easy to shape.

Lead is a very soft heavy gray metal having a fracture with a dull lustre; it shapes easily.

Tin is a very soft silvery gray metal, readily shaped. Tin can be rolled into very thin sheets (foil).

Aluminium is a soft white metal with a bluish tint; it shapes readily hot or cold.

NONFERROUS ALLOYS

In the manufacture and repair of contractor's machines, alloys of copper, zinc, lead, tin and aluminium are employed,

for parts subjected to friction or corrosion. The most commonly used are such alloys as bronze, brass, babbitt and solders.

Bronze is an alloy composed mainly of copper and tin, and sometimes containing phosphorus, zinc, lead, nickel, aluminium, manganese, arsenic, iron and/or beryllium. Bronze is reddish yellow in colour, and is noted for good mechanical and casting properties. Bronzes are graded according to chemical composition which is indicated in their grade index. The elements are denoted by the following letters of the Russian alphabet: Бр, bronze; О, tin; Ф, phosphorus; Ц, zinc; С, lead; Н, nickel; А, aluminium; Мц, manganese; М, arsenic; Ж, iron; Б, beryllium. The digits in the grade index give the average content of the respective constituent.

The following bronzes are used in the manufacture of contractor's machines: wrought tin bronze (БрОФ6.5-0.15) for bearings, springs, pressings, strips, bars and wire; cast tin bronze (БрОЦС6-6-3), for casting friction parts; aluminium bronze (БрАЖ9-4) for casting and forging critical heavy-duty parts subject to hard wear, such as stuffing boxes, gears, screws, nuts and certain parts of pumps.

Brass is an alloy of copper and zinc. Brass is yellow in colour. The percentage of zinc in various grades of brass may be up to 50. Besides zinc, brass may contain other elements which improve its strength, hardness, casting properties, workability and machinability.

Grade indexes of brass consist of Russian letters and numbers. The letter Л stands for brass, С for lead, А for aluminium, Ж for iron, Н for nickel, Мц for manganese, О for tin, К for silicon. The first numeral following the letters indicates the copper content, and the rest the contents of the respective elements.

The following grades of brass are used in contractor's machine parts: Л62, for corrosion-resistant parts, screens, gaskets and for parts that are to be cold-forged; ЛС59-1, for parts that are to be hot-forged and machined; ЛМцС58-2-2, for making shells, bushings and other friction parts.

Babbitt is an alloy belonging to the bearing or so-called antifriction alloys. It is used to coat (line) the working surface of a bearing to reduce the friction between the bearing and the shaft rotating in it.

Depending on its composition, babbitt may be *tin-base* or *lead-base.*

The most commonly used babbitt in contractor's machines is grade БН, containing about 9-11 per cent tin and about 78 per cent lead.

Solders are alloys which are used for joining metal parts by soldering. There may be soft solders and hard solders, or spelters.

Soft solders are alloys of lead and tin. Grade ПОС-30 soft solder containing 70 per cent lead and 30 per cent tin is used for tinning bearing surfaces before lining with babbitt.

Spelters of grades ПМц-36, ПМц-54, etc., containing 36-54 per cent copper and 46-64 per cent zinc are employed for brazing only.

SUBSTITUTES FOR NONFERROUS METALS

Nonferrous metals and alloys are very expensive materials and therefore the tendency has been to replace them by cheaper materials. For instance, bronze bearings can be replaced by bearings made of *antifriction cast iron*, such as grades СЧЦ-1 and СЧЦ-2; if well machined and lubricated, and used in well-balanced machinery, it is a good substitute for bronze. Other substitutes for nonferrous metals, used in bearings and other machine parts, are *untreated compressed wood, indurated plywood* and *fabric-base resin-bonded laminates.*

In mechanical engineering wide use is made of plastics based on resins, esters, cellulose, etc. Owing to their low specific gravity (0.04-0.5 g), considerable mechanical strength and wear resistance, these materials are good substitutes for nonferrous and ferrous metals.

CORROSION OF METALS

Metal corrosion is a chemical or electrochemical process which begins at the surface of a metal and gradually destroys it.

Corrosion may be due to the action of gases, acids and alkalis present in the ambient air, in the combustion products of fuel, in water and in the soil. Besides, two different

metals, such as copper and steel, if mated in a machine, may give rise to electric currents which cause electrochemical corrosion.

Metals of different chemical composition have different corrosion resistance. For instance, the presence of sulphur in a metal will lower its resistance to corrosion, while the presence of chromium and nickel will increase it. Iron and steel are more apt to corrode than nonferrous metals and alloys (bronze, brass).

Corrosion resistance also depends on the surface finish of a part. A highly polished surface resists corrosion better than a rough one.

Corrosion can be prevented by the use of metals of special composition; giving the part a coating of a noncorroding metal (chromium, nickel, etc.); painting and lubricating the part; taking proper care of machines (cleaning to remove moisture, adhering soil and building materials).

2. Service Materials

Proper operation of contractor's machinery calls for a number of service materials.

These are lubricants, rags and waste, packing, sealing and abrasive materials, as well as conveyor and transmission belts, steel ropes, chains and hose.

LUBRICANTS, RAGS AND WASTE

Lubricants. When in operation, most parts of a machine are in motion. In order to reduce friction and wear in the machine, the rubbing surfaces must be lubricated. A thin layer of lubricant separating the rubbing surfaces decreases the friction between them.

The quality characteristics of lubricants are lubricity (or oiliness), viscosity, flash and congealing points, impurity content, oxidizability, carbon-residue formation, etc.

Lubricity, or *oiliness*, is the ability of a lubricant to form a strong film on the metal surface. Lubricity depends on the chemical composition of the oil.

Viscosity is the resistance offered by a lubricant to relative motion of its particles, i.e., it characterizes the internal

friction of the oil. It decreases with rising temperature and increases with falling temperature. The higher the load on the rubbing surfaces and the lower their speed, the greater must be the viscosity of the oil.

Flash point is the temperature to which an oil must be heated until sufficient flammable vapour is driven off to flash when brought in contact with a flame.

Congealing point is the temperature at which the oil congeals, i.e., loses fluidity. In the cold seasons machines are lubricated with lower-congealing grades, because an oil with a high congealing point will congeal quickly and become very thick in the cold. If such a lubricant is used, the machine is difficult to start up.

Lubricants fall into two groups: lubricating oils and greases.

Lubricating oils are manufactured by fractionation of crude petroleum and are refined in special units.

Greases are mixtures of 75-90 per cent mineral oils compounded with soaps (salts of higher fatty acids). They are employed where an oil will not reach points of lubrication, or parts operate in a dusty atmosphere. The grease fills the gaps and keeps dust out.

Lubricants must not contain water or solid impurities. The presence of water in a lubricant is easy to detect, because oil and water do not mix and the interface between them is easy to distinguish. Solid impurities (grit, etc.) can be detected in a lubricant by rubbing it between the fingers.

Lubricants are tested for quality at laboratories.

Lubricants should be stored in covered containers, viz., barrels or cans. Lubricating systems should be filled by means of special pails and funnels with wire filters having 144 meshes per square centimetre. Before filling oil cans, the oil must be allowed to settle.

Machines must never be oiled with dirty lubricants. If the lubricant is dirty, the parts will wear out quickly. To save lubricants, spent oils should be reused after cleaning them to remove impurities. The simplest method of cleaning is by settling.

Table 3 lists the grades of lubricants used in contractor's machinery.

Table 3

Lubricants and Their Uses

Lubricant	Application
Liquid oils	
Industrial 30 (machine Л), GOST 1707-51	Mechanical joints
Industrial 45 (machine С), GOST 1707-51	Worm gears
Cylinder 24, GOST 1841-51	Steam engine cylinders
Motor M, GOST 1519-42	Internal combustion engines
АК10 (avtol 10), GOST 1862-60	Automobile and tractor engines
АК15 (avtol 15), GOST 1862-60	Ditto
Greases	
Cup grease $УС_С$-1, $УС_С$-2, GOST 4366-56	General purpose
Constalin $УТ_С$-1, $УТ_С$-2, GOST 5703-51	Roller and ball bearings
Graphite grease УСА, GOST 3333-55	Gears, chains
Rope grease ИК, GOST 5570-50	Steel ropes

Rags and Waste. Machines are wiped with waste and rags. Waste is cotton thread rejects and refuse. Rags are cotton or linen and are cleaned and disinfected before use.

PACKING AND ABRASIVE MATERIALS

Packing Materials. The following materials are employed as packing materials: manufactured asbestos and rubber, paper, paperboard, felt, tow, and hemp.

Asbestos is a fibrous mineral consisting of silica, magnesium oxide and calcium oxide. Asbestos fibres may be up to 300 mm long and 0.2 to 1 mm thick. Asbestos is very strong, elastic and is a poor conductor of heat and electricity.

Asbestos is made up in a variety of forms widely used in mechanical engineering, such as yarn, cord, felt, cloth, metallic asbestos tape, impregnated asbestos board, etc.

Asbestos yarn, cord, felt and cloth are used as stuffing, sealing and packing materials to prevent leakage of liquids, steam and gases.

Asbestos fabric reinforced with fine copper wire (known under the proprietary name of *ferodo*) is used to line steel brake bands and friction mechanisms. This material is manufactured as bands of various thicknesses and lengths, as well as blocks of various shapes and sizes.

Rubber is a product obtained by treating crude rubber with substances called vulcanizers (sulphur, sodium, etc.). Rubber is highly elastic, resistant to vibrations, strong and possesses other valuable properties owing to which it is widely used in mechanical engineering.

Green rubber products are made from a rubber compound known as a master batch which includes vulcanizers, accelerators (lead oxide), reinforcing agents (carbon black), softeners (oils), fillers (chalk) and substances which increase the lifetime of rubber products.

To lower the elasticity and raise the strength of rubber it is reinforced with fabric, metal gauze or wire.

The raw rubber is machined into gaskets, belting, hoses, valves, tyre tubes, tyres, etc. The green rubber products are then vulcanized, i.e., heated to about 140°C in steam under a pressure of about 3 atm. Vulcanization involves complex chemical processes as a result of which the rubber acquires the properties indicated above.

Rubber packings are made in many different forms: gaskets, valve disks and seats, shaft packings, etc.

Rubber gaskets are used to prevent leakage of hot water.

Paronite is the proprietary name for a sheet-type material made of asbestos and rubber. Paronite gaskets are resistant to gasoline and oils.

Paper and paperboard gaskets are used to seal joints not exposed to heat.

Vulcanized or *hard fibre* is produced by treating cotton-base paper with a zinc chloride solution. The treated paper is then laminated to the desired thickness. The material is strong, easy to machine and can be used as insulation.

Felt is used in mechanical engineering for making gaskets. Felt gaskets keep grit out of bearings, protect them from corrosion, etc.

Abrasives. Abrasives include emery, corundum, carborundum, etc. They are made into grinding wheels, grinding stones, emery paper, polishing powders and pastes, which are used for machining metal parts to precise dimensions and high finish.

CONVEYOR BELTS

Conveyor belts are made of rubber-bonded or plain cotton fabrics, of thin steel strips, or are woven from steel wire. In these machines the belt is the tractive part and simultaneously supports and transports the material handled.

The standard construction of *rubber belts* for use in civil engineering has several plies of cotton duck cemented together with a rubber compound. The number of plies depends on the tension and width of the belt (Table 4).

Table 4

Number of Plies as a Function of Belt Width

Ply fabric	Belt width, mm										
	300	400	500	650	800	1,000	1,200	1,400	1,600	1,800	2,000
	Number of plies										
ОПБ-5 or ОПБ-12	—	—	—	3-5	3-6	3-8	3-8	3-8	3-8	3-8	3-8
Б-820	3-5	3-8	3-9	3-10	3-11	3-11	3-12	3-12	3-12	3-12	3-12

The top and bottom sides of the belt are covered with rubber to resist abrasion and keep out moisture. The thickness of the top cover is determined by the severity of the job and may be up to 6 mm (see Table 5).

Rubber belting is marketed in rolls up to 120 m long. The ends of the belt are joined to make an endless belt needed for use in a conveyor.

Cotton belts are employed only indoors for handling dry and nontacking materials, because they readily absorb moisture and wear out quickly.

Steel belts made of thin steel strip are used for conveying hot materials or materials with sharp edges.

Table 5

Thickness of Rubber Cover as a Function of Material Handled

Medium-hard materials	Cover thickness, mm	
	Top side	Bottom side
Fine-grained	1.5	1
Coarse-grained	3	1.5
Lumps	4.5	1.5

Steel wire mesh belts are used for handling materials with sharp edges or when the material has to be sifted or dried during handling.

TRANSMISSION BELTS

As their name implies, transmission belts are used in drives for power transmission. Contractor's machinery uses flat and V-belts.

Flat rubber transmission belts have several plies of cotton fabric bonded together with vulcanized rubber compound. Belts are put out with or without rubber covers; rubber-covered belts give good service in damp places, resist attack by acids and alkalis, but are sensitive to changes in temperature and to attack by mineral oils.

Flat rubber belts may be of three types: raw edge (Fig. 4*a*, *b*), folded edge (Fig. 4*c*, *d*) and spiral ply (Fig. 4*e*, *f*).

Transmission belting is put out in widths of 20, 25, 30, 40, 50, 60, 70, 80, 100, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, and 500 mm.

The number of plies in a belt depends on its type and width.

The widths and number of plies of various types of rubber transmission belting are given in Table 6.

Rubber belting is delivered in lengths of:

8 m and more when up to 80 mm wide;

20 m and more when 100 to 250 mm wide;

30 m and more when 300 mm wide or more.

Rubber V-belts are of trapezoidal cross section and ride in

Table 6

Width and Number of Plies of Rubber Belting

Type of belting			Number of plies recommended
Lengthwise cut	Layer enveloped	Spirally enveloped	
Belt width, mm			
—	20-40	—	2
—	—	20-40	3
50-70	—	50-70	3-5
80-100	—	80-100	3-6
125-225	175-225	125-225	4-6
250-300	250-300	250-300	4-7
350-450	350-450	350-450	5-8
500	500	500	—

Table 7

Cross Sections of V-Belts

Belt cross-section designation	Cross-sectional dimensions (Fig. 5)		
	Width a, mm	Thickness b, mm	Cross-sectional area, cm²
О	$10^{+0.4}_{-0.3}$	6 ± 0.3	0.47
А	$13^{+0.6}_{-0.4}$	8 ± 0.4	0.81
Б	$17^{+0.7}_{-0.5}$	10.5 ± 0.5	1.38
В	$22^{+0.8}_{-0.5}$	13.5 ± 0.5	2.30
Г	$32^{+0.9}_{-0.6}$	19 ± 0.5	4.77
Д	$38^{+1.0}_{-0.7}$	23.5 ± 0.7	6.92
Е	$50^{+1.0}_{-0.8}$	30 ± 0.8	11.70

V-shaped pulley grooves (Fig. 5); V-belts make a tighter fit, and hence their grip on the pulley is better than in the case of flat belts.

V-belts are put out in two types, viz., *cord fabric* and *cord wire*. In the former (Fig. 6*a*) the load-carrying layer consists of several rows of thin cotton cord; in the latter (Fig. 6*b*) the load-carrying layer consists of a single row of thick cotton cord. Cord wire V-belts are more pliable and wear-resistant, but also more expensive. Cord fabric belts are used under ordinary conditions, and cord wire belts for heavy-duty operation.

According to GOST 1284-57, V-belt cross sections are denoted by letters of the Russian alphabet. Table 7 lists the cross sections of V-belts, and Table 8, their longths.

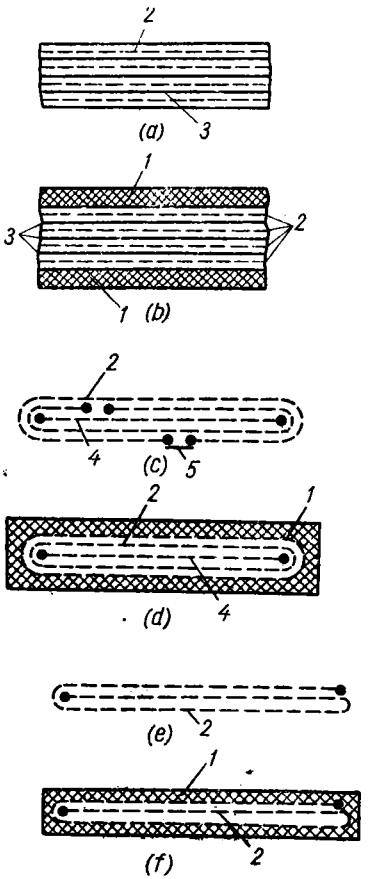


Fig. 4. Types of flat rubber belting:
(*a*) raw edge, uncoated, (*b*) raw edge, rubber-coated, (*c*) folded edge, uncoated, (*d*) folded edge, rubber-coated, (*e*) spiral ply, uncoated, (*f*) spiral ply, rubber-coated; *1*—rubber coat, *2*—fabric ply, *3*—rubber layer, *4*—central ply, *5*—rubber strip

WIRE ROPES

Wire ropes are employed extensively in hoisting and contractor's machinery. Wire ropes are not very heavy and they are flexible and quiet in operation.

To make a rope wires are twisted into strands which are then twisted into the rope.

Depending on its ductility, the wire used to make ropes may be of grades B, I and II. Ropes of grade B wire are

Table 8

Standard V-Belt Data (mm)

Rated (inside) belt length	Calculated lengths for belt sizes						
	О	А	Б	В	Г	Д	Е
500	519	525	—	—	—	—	—
560	579	585	—	—	—	—	—
630	649	655	663	—	—	—	—
710	729	735	743	—	—	—	—
800	819	825	833	—	—	—	—
900	919	925	933	—	—	—	—
1,000	1,019	1,025	1,033	—	—	—	—
1,120	1,139	1,145	1,153	—	—	—	—
1,250	1,269	1,275	1,283	—	—	—	—
1,400	1,419	1,425	1,433	—	—	—	—
1,600	1,619	1,625	1,633	—	—	—	—
1,800	1,819	1,825	1,833	1,844	—	—	—
1,900	1,919	1,925	1,933	1,944	—	—	—
2,000	2,019	2,025	2,033	2,044	—	—	—
2,120	2,139	2,145	2,153	2,164	—	—	—
2,240	2,259	2,265	2,273	2,284	—	—	—
2,360	2,379	2,385	2,393	2,404	—	—	—
2,500	2,519	2,525	2,533	2,544	—	—	—
2,650	—	—	—	2,694	—	—	—
2,800	—	2,825	2,833	2,844	—	—	—
3,150	—	3,175	3,183	3,194	3,210	—	—
3,550	—	3,575	3,583	3,594	3,610	—	—
4,000	—	4,025	4,033	4,044	4,060	—	—
4,500	—	—	4,533	4,544	4,560	4,574	—
5,000	—	—	5,033	5,044	5,060	5,074	—
5,600	—	—	5,633	5,644	5,660	5,674	—
6,300	—	—	6,333	6,344	6,360	6,374	4,395
7,100	—	—	—	7,144	7,160	7,174	7,195
8,000	—	—	—	8,044	8,060	8,074	8,095
9,000	—	—	—	9,044	9,060	9,074	9,095
10,000	—	—	—	—	10,060	10,074	10,095
11,200	—	—	—	—	11,260	11,274	11,295
12,500	—	—	—	—	—	12,574	12,595
14,000	—	—	—	—	—	14,074	14,095

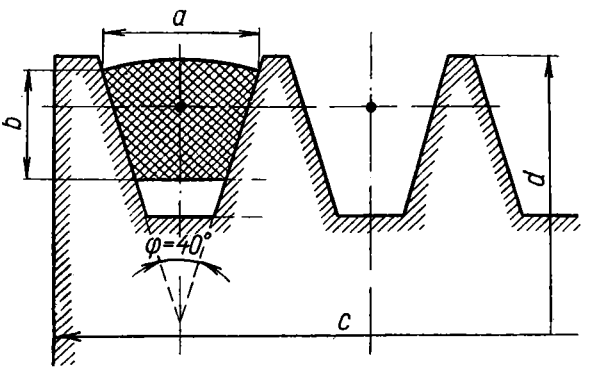


Fig. 5. Section of V-belt and groove of V-belt pulley:
(*a*) width of upper base of trapezoid (belt width), (*b*) height of trapezoid (belt thickness), (c) pulley width, (*d*) outer diameter of pulley

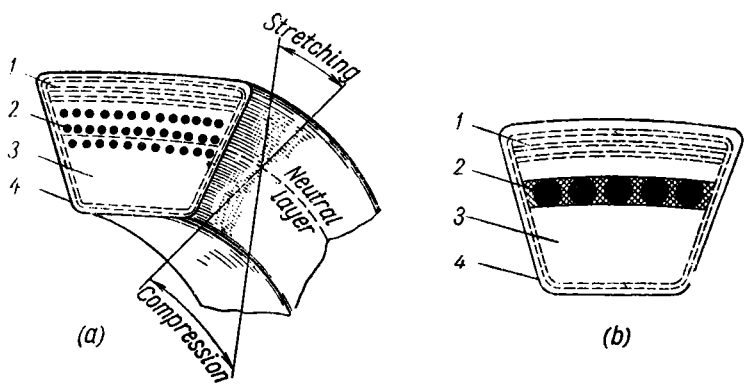


Fig. 6. Structure of V-belts:
(*a*) cord fabric, (*b*) cord wire; *1*—stretching layer (rubber-coated duck), *2*—neutral layer (cord), *3*—compression layer (rubber), *4*—outer coat or rubber-coated duck

used in critical applications (passenger lifts); ropes for contractor's machinery are made of grade I wire.

To improve flexibility, increase resistance to impact loads and distribute stresses evenly ropes are made with a hemp of cotton core impregnated with mineral oil. Ropes may have one or more cores.

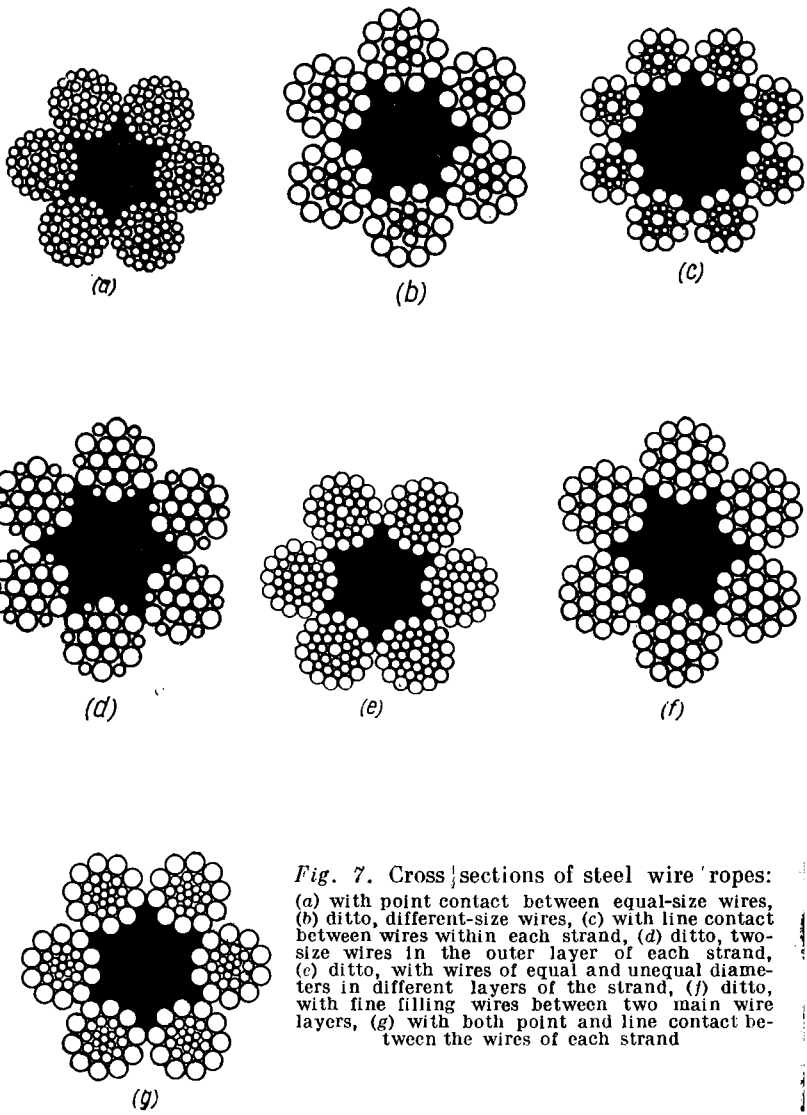


Fig. 7. Cross-sections of steel wire ropes: (*a*) with point contact between equal-size wires, (*b*) ditto, different-size wires, (*c*) with line contact between wires within each strand, (*d*) ditto, two-size wires in the outer layer of each strand, (*e*) ditto, with wires of equal and unequal diameters in different layers of the strand, (*f*) ditto, with fine filling wires between two main wire layers, (*g*) with both point and line contact between the wires of each strand

Wire ropes may be classified according to cross section, type, kind and direction of twist.

Ropes may be round or flat in *cross section*; only round ropes are employed in contractor's machinery.

According to *type of twist* there are:

type TK, with point contact between the wires of the strand layers, the wires being of the same (Fig. 7*a*) or different (Fig. 7*b*) size;

the type featuring line contact between the wires within each strand. This type is subdivided into the one-size-wire type, designated LK-O (Fig. 7*c*); the two-size-wire type, designated LK-P (Fig. 7*d*); ropes with wires of equal and unequal diameters in different layers of the strand, designated LK-PO (Fig. 7*e*); ropes with fine filling wires between two main wire layers, designated LK-3 (Fig. 7*f*); ropes with both point and line contact between the wires of each strand, designated TLK (Fig. 7*g*).

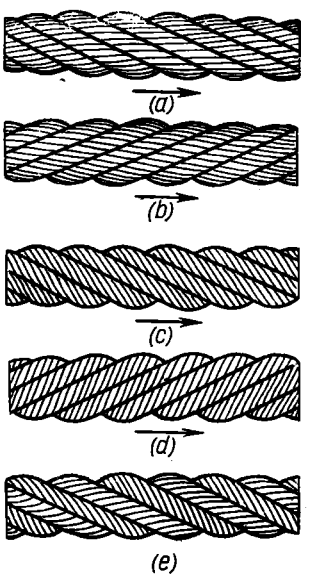


Fig. 8. Direction of twist of wire ropes:
(*a*), (*b*) regular-lay, (*c*), (*d*) lang-lay, (*e*) reverse-laid

With respect to *kind of twist* ropes may be of the type that untwist when cut; nonuntwisting ropes; nonrotating multiple layer ropes with strands of different layers twisted in opposite directions.

Depending on the *direction of twist* ropes may be regular-lay, lang-lay, and reverse-laid.

In regular-lay ropes (Fig. 8*a*, *b*) the strands are twisted to the right and the rope to the left. In lang-lay ropes (Fig. 8*c*, *d*) both the wires in the strands and the strands in the rope are twisted in the same direction.

Lang-lay ropes are more flexible and have a larger area of contact with the pulley or drum surface. But when very

long, they tend to untwist and therefore in contractor's machinery regular-lay ropes are preferred.

In reverse-laid ropes (Fig. 8*e*), alternate strands are right and left lay.

Ropes may be of right or left twist.

Winches, elevators, cranes, conveyors, concrete mixers, mortar mixers, diesel hammers, etc., use TK type ropes.

CHAINS

The chains employed in contractor's and hoisting machinery may be divided into three groups: transmission, crane and hoisting, and haulage. Each group includes several types.

Transmission chains (Fig. 9) transmit power from the prime mover to the machine or from one machine to another.

A transmission chain is a series of links consisting of several plates hinged together by pins and bushings; this type is known as flat-link chains. The links of a flat-link chain can bend only in one direction. A chain is characterized by its pitch. The pitch of a flat-link chain is the distance between the centres of the holes in the link plates. The ends of a flat-link chain are joined by connecting links.

Bushed-roller, bushing and toothed flat-link chains are the most commonly used in drives.

A *flat-link bushed-roller chain* (Fig. 9*a*, *b*, *c*) consists of pin-link *1* and inside *2* plates assembled with pins *3* and bushings *4*. The ends of the pins are secured in the pin-link plates. The bushings are mounted on the pins and secured to the inside or roller-link plates. The rollers *5* are free to rotate on the bushings and serve as the elements through which the chain makes contact with a sprocket.

Flat-link bushed-roller chains may have straight or offset link plates, a single strand or multiple strand. A multiple-strand chain is made up of single-strand chains connected by elongated pins.

Bushed-roller transmission chains are put out with pitches of from 8 to 65 mm.

A *flat-link bushing chain* (Fig. 9*d*) differs from the bushed-roller type chain in that it has no rollers. These chains may have straight or offset link plates. Transmission bushing chains are made with pitches ranging from 15 to 100 mm.

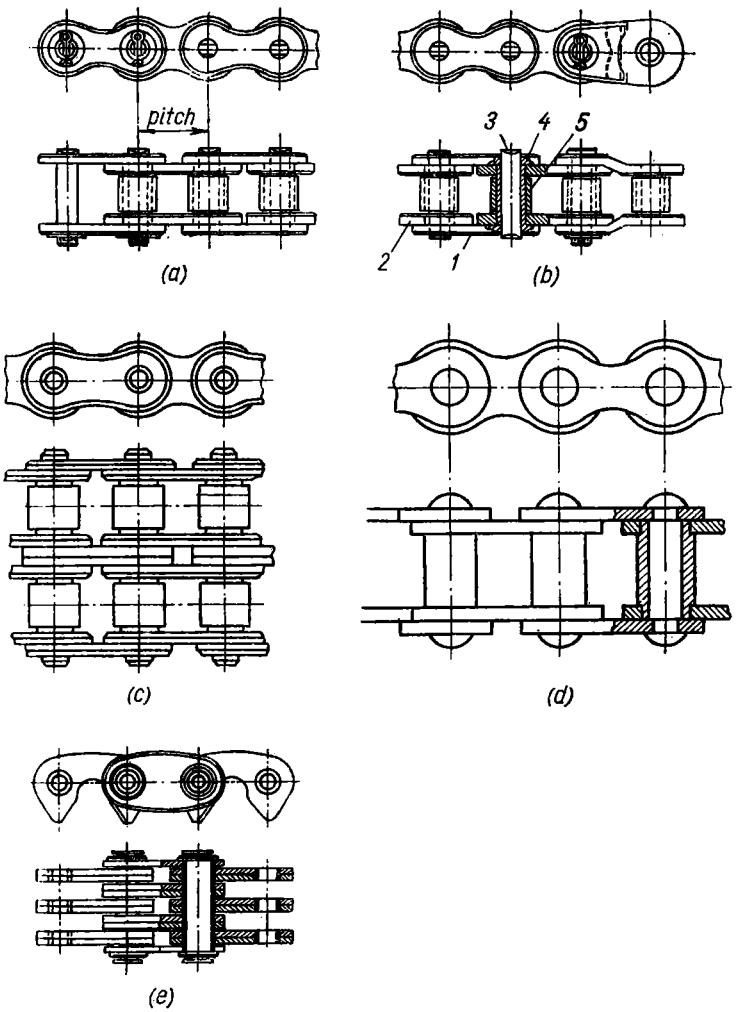


Fig. 9. Transmission chains:

(*a*) single-strand flat-link bushed-roller chain with straight link plates, (*b*) ditto, with bent link plates, (*c*) multiple-strand flat-link bushed-roller chain with straight link plates, (*d*) flat-link bushing chain, (*e*) flat-link inverted-tooth chain; *1*—pin-link, *2*—inside link, *3*—pin, *4*—bushing, *5*—rollers

A *flat-link inverted-tooth* (or *silent*) *chain* (Fig. 9*e*) is made up of toothed link plates. The plates of each link are held together by bushings, each connecting several plates of a link. The sets of plates of one link are connected to those of the next by means of pins. These chains have special guide plates, and they engage the sprockets by the teeth extending across the underside.

Inverted-tooth or silent chains may have a pitch of from 9.52 to 38.1 mm. They are employed for power transmission from a prime mover to a machine.

Load chains (Fig. 10) are used for suspending or hoisting loads. They may be flat-link or welded.

A *flat-link load chain* (Fig. 10*a*) has links consisting of an even number of plates hinged together with pins. They are used for speeds not exceeding 1.5 m/s. Flat-link load chains are made with pitches ranging from 15 to 140 mm.

Welded load chains (Fig. 10*b*) are series of interlinked oval rings made of mild rounds. The links of such chains are made by bending on special machines and welding.

The pitch of a welded chain is the length of the major axis of the oval opening of a link.

The ends of welded chain are joined by means of special links which can be bent in any direction. With respect to accuracy of manufacture, welded chains may be sized and ordinary. Sized chains have more accurate dimensions and are therefore recommended for power transmission. When a load is hoisted by means of a welded chain, it must be moved at low speed (not over 1 m/s).

Sized chains are made of rounds from 5 to 41 mm in diameter; their pitch ranges from 19 to 64 mm.

Haulage chains (Fig. 11) are employed for moving loads in buckets, trucks and other devices attached to these chains.

Haulage chains may be flat-link or welded. A *flat-link haulage chain* consists of links formed alternately by two outer and two inner plates hinged together.

Flat-link haulage chains may be without bushings and with or without rollers; with bushings and without rollers (Fig. 11*a*), with rollers (Fig. 11*b*), and with flanged rollers (Fig. 11*c*).

These chains are put out with the following pitches: from 60 to 300 mm for chains without bushings and with or

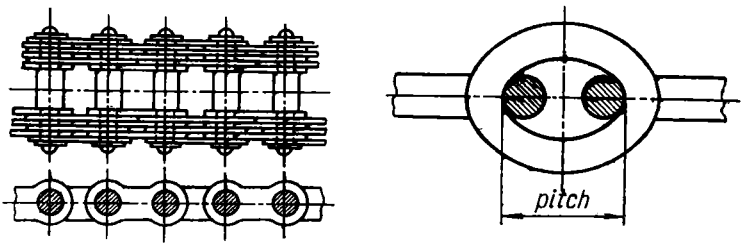


Fig. 10. Load chains:
(*a*) flat-link, (*b*) welded

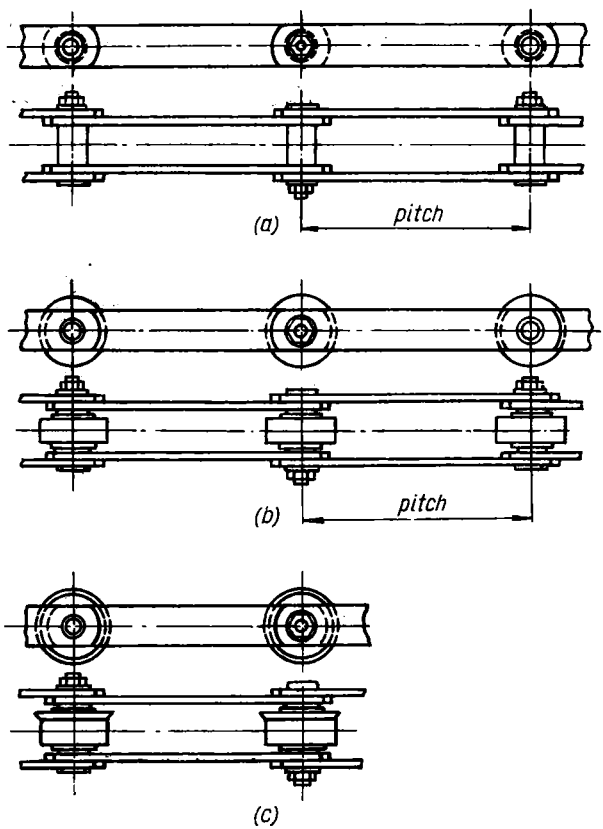


Fig. 11. Haulage chains:
(*a*) with bushings and without rollers, (*b*) with rollers, (*c*) with flanged rollers

without rollers; from 100 to 1,250 mm for bushing chains without rollers; from 60 to 1,250 mm for bushed-roller chains, and from 75 to 1,250 mm for flanged-roller chains.

Welded haulage chains differ from welded load chains in that the former are furnished with special links to which the devices for moving materials and articles are attached.

HOSE

Hose is used for conveying gas, liquids, loose materials, solutions and concrete mixes.

As to purpose, one distinguishes pressure and vacuum hoses; in pressure hoses the material is moved by the pressure set up in the hose; in vacuum hoses, this is done by vacuum.

Pressure hoses have an inner lining of rubber, several plies of rubberized fabric and an outside rubber coat. These hoses may be up to 20 m long and up to 150 mm in diameter.

Vacuum hoses differ from pressure hoses in that they have a spiral wire reinforcement inside the hose wall. Such hoses are made in lengths up to 8 m and in diameters up to 305 mm.

3. *Rock Materials Used in Civil Engineering*

The materials of this type include sand, gravel, crushed stone.

Sand is a mixture of quartz grains (in the 0.15-5 mm size range) often containing other substances. There are three main types of sand: bank or river sand, beach or sea sand, and pit-run sand.

Bank and beach sands have rounded grains; pit sand is harsh. Bank and beach sands contain less impurities than pit sands.

Pure sharp sand is recommended for concrete mixes, because its grains adhere well to the cement, making the concrete stronger.

Gravel is a natural loose material with rounded grains ranging in size from 5 to 150 mm.

Crushed stone or *rubble* is an artificial loose material with grains 5 to 150 mm in size, and of sharp angular shape, in contrast to gravel.

Rubble is produced by crushing natural stone (granite, diabase, limestone, sandstone, etc.), brick or slag. Crushed natural stone is free from clayey or other impurities. Rubble is often made from used bricks after the latter have been cleaned of mortar.

Brick rubble has to be saturated with water before using it in a concrete mix, since otherwise it will take water from the mix, lowering the quality of the concrete.

Rubble is also prepared from lump slag. This rubble is gray in colour and very strong. It is a by-product of blast and open-hearth furnaces.

CHAPTER TWO

HOW TO READ MECHANICAL DRAWINGS

Mechanical drawings are graphical representations of machine parts, whole machines, buildings, structures and other objects.

Drawings are indispensable in mechanical and civil engineering, as well as in other branches of industry. Depending on the purpose of the objects depicted, the following kinds of drawings are distinguished: machine drawings, structural drawings, etc.

Drawings must give exhaustive information as to the shape, dimensions and arrangement of the objects depicted on them (machine parts, machines, structures, etc.). No description of the object can give a complete idea of it, i.e., substitute a drawing.

Drawings are made to special rules, using drawing instruments and materials.

The rules for making machine drawings are covered by U.S.S.R. State Standards.

GOST stipulate sheet sizes, the kinds of lines to be used, dimensioning rules, etc.

GOST facilitate the execution and reading of drawings.

4. Projections and Projection Drawing

Mechanical drawings are obtained by projecting the object to be drawn. The most commonly used method is that of projecting on to a plane.

To *project on to a plane* means to transfer a view of the object on to the plane; the image obtained on the plane is called its *projection.*

To project an object on to a plane it should be placed stationarily between the eye and the plane, or, if this is impossible, the object should be imagined in such a position.

Depending on the angle at which the object is viewed, different projections can be obtained on the plane.

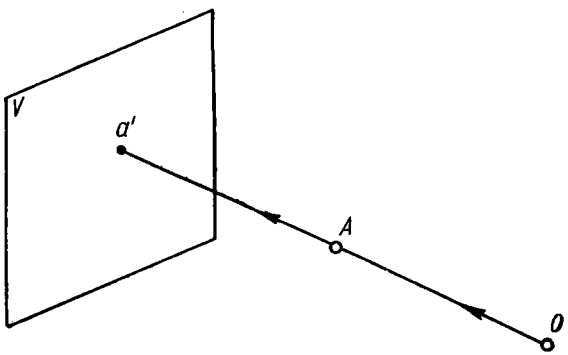


Fig. 12. Vertical projection of a point

Mechanical drawings of objects should be made by orthographic projection. This method may be explained by the following examples.

Suppose point A (Fig. 12) is situated between the eye O and the vertical plane V. The line of vision passes through A at right angles to V. The point of intersection a' of the line of vision with plane V is called the *vertical projection* of point A.

In a similar way the projection of A on to a horizontal plane gives its *horizontal projection.*

In the cases just considered the lines of vision intersect the vertical and horizontal planes at right angles, and that is why this method of projecting is called *orthographic*, and the projections are known as *orthographic projections.*

According to the plane (surface) of the object on which the line of vision falls the projection may be a front view, top view, left-side view, right-side view, bottom view and rear view.

According to GOST views are arranged on a drawing in the following order: the top view is placed below the front

view, the left-side view at its right, and the right-side view at its left, level with the front view, the bottom view is placed above the front view, and the rear view, at the right of the left-side view.

With this disposition of views on the drawing (Fig. 13) the front view becomes the main view, and it should give the most complete idea of the projected object.

This relation in arrangement of the views is called the *projection relation.* Most often three projection planes at right angles to each other are used (Fig. 14), the intersections of these planes being referred to as the *projection axes.*

The distance of the various views from the projection axes should be equal to the preset distance between the object being drawn and the corresponding projection planes.

Before making the drawing, mark the boundaries on the paper with light lines.

Draw the title box in the lower right-hand corner inside the boundary lines in the form of a table containing the basic data: name of object, date of execution, name of draftsman, etc. Draw the table with light lines.

Finished drawings should be rectangular in shape and of one of the sheet sizes provided for by GOST (Table 9).

Table 9

Sheet Sizes for Finished Drawings According to GOST

Sides of sheet, mm	814×1,152	576×814	407×576	288×407	203×288
Size No.	0	1	2	3	4

In machine drawings machine elements and the machines themselves are rarely drawn to natural size or full scale, as it is called; in the drawing large machines and machine parts are scaled down or reduced, while small ones are scaled up or increased in size.

The *numerical scale* of a drawing is the ratio of the dimensions of the drawn image to the actual dimensions of the object.

If the dimensions of an object on the drawing are smaller than its actual dimensions, the drawing is said to be made

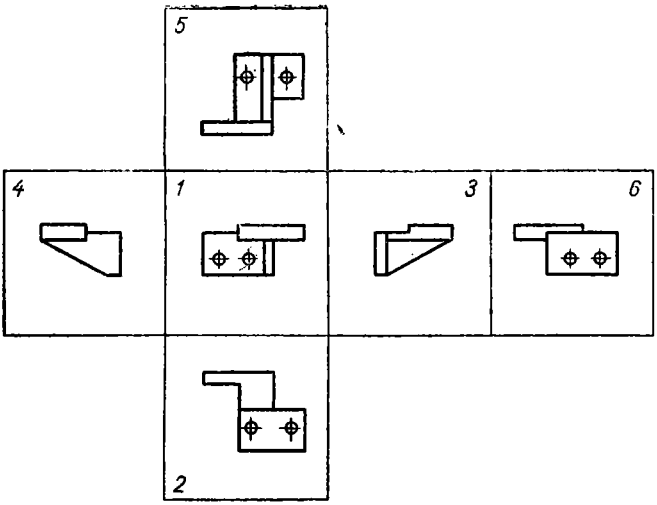


Fig. 13. Arrangement of views on a drawing

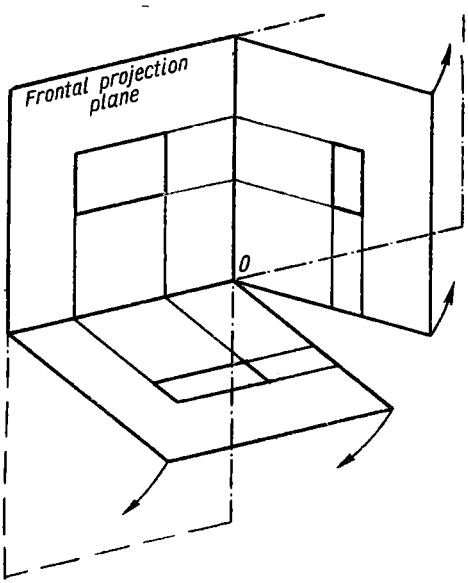


Fig. 14. Planes and axes of projection

to a reduced scale; if they are larger, it is said to be made to an enlarged scale.

Independent of the scale, the dimensions indicated in the drawing must be the actual dimensions of the object.

The following scales are provided by GOST for machine drawings: reduced scales—1 : 2; 1 : 5; 1 : 10; enlarged scales—2 : 1; 5 : 1; 10 : 1; this means that the dimensions in the drawings must be reduced or increased twofold, fivefold or tenfold with respect to the actual dimensions.

In drawings the scale is indicated thus:

M 1 : 1 for full scale
M 1 : 2, M 1 : 5 or M 1 : 10 for reduced scales
M 2 : 1, M 5 : 1 or M 10 : 1 for enlarged scales.

The U.S.S.R. State Standard provides for the use of solid, dash, dot-and-dash, wavy and other lines (Fig. 15).

5. Drawing Practice

The width or weight of the solid lines with which the visible outlines of the object are drawn is selected depending on the size and complexity of the latter. The weight must be the same on the whole drawing; the weight of all other lines depends on the weight selected for the visible outlines.

Only those dimensions should be given in the drawing which are essential and sufficient to give an idea of the object so that it can be made from the drawing.

The principal rules of GOST for dimensioning machine drawings may be presented as follows: fine solid lines (extension lines) are drawn to indicate the ends of the interval measured (Fig. 16), to show the dimension fine solid dimension lines are drawn between the extension lines. Dimension lines may also be drawn between visible outlines and centre lines.

According to GOST, dimensions are written above the dimension lines (Fig. 16).

In machine drawings dimension lines have arrowheads at their ends, the points of which touch the lines between which the dimension is indicated (extension lines, outlines, etc.).

Dimensions given in millimetres in machine drawings are not followed by the abbreviation mm.

Line	Representation	Weight ratio	Uses
1.Solid visible		b	Visible outlines Outlines of detail section
2.Solid fine		b/3 and less	Outlines of revolved section Dimension and extension lines Cross-hatch lines Extension lines Lines showing boundaries of parts of outside and sectional views, broken out for detail sectioning Projection axes
3.Solid wavy		b/2 and less	Break lines (except for wood)
4.Dashed		From b/2 to b/3	Invisible outlines
5.Dash-and-dot, fine		b/3 and less	Axis and centre lines

Fig. 15. **Lines used in drawings**

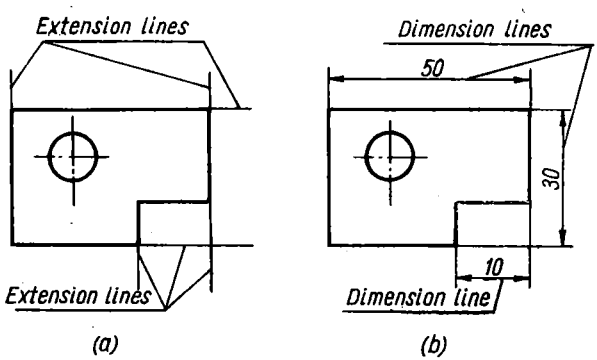


Fig. 16. **Dimensioning drawings**

If other units of measurement are used the abbreviation of the unit, e.g., cm or m is affixed to the numerical value.

All inscriptions on machine drawings should be made in lettering of the type and size provided for by GOST.

6. Sectional Views

The plane figure that results if we intersect a part with a plane is called a *section.* Sections in drawings are cross-hatched. The types of cross-hatching to be used are established by GOST according to the material of the object in question (steel, cast iron, etc.).

Cross-hatching is done with straight parallel lines inclined to the right or left at 45° to the centre line, and spaced at from 1 to 4 mm. The cross-hatching of all the sections of the same object in a drawing should be inclined in the same direction.

In drawings, sections may be arranged outside of or within the outline of the projection; in the former case they are called detail sections, in the latter—revolved sections.

Detail sections may be set off in any free space within the limits of the same view.

The visible outline of a detail section is drawn in solid heavy lines (Fig. 17), and of a revolved section, in fine solid lines (Fig. 18).

To bring out the internal outlines of an object (part or assembly of parts) more vividly in the drawing, the object is presented as if intersected by a cutting plane with the front part of the object removed.

This conventional representation is known as a "sectional view"* (Fig. 19), the sectioned part of the object being projected and drawn as usual, i.e., everything that can be seen in the plane of the section (in the cutting plane) and beyond it, is drawn (Fig. 20). Thus, a *section* is a conventional drawing of an object, part of which (that between the eye and the cutting plane) has imaginarily been removed, showing everything that would be seen in the cutting plane (the section) and beyond it.

* Sectional views are often also called sections in English.—*Tr.*

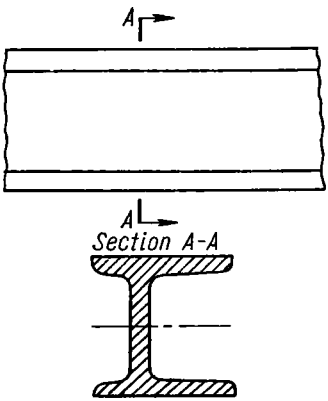


Fig. 17. Disposition of detail section

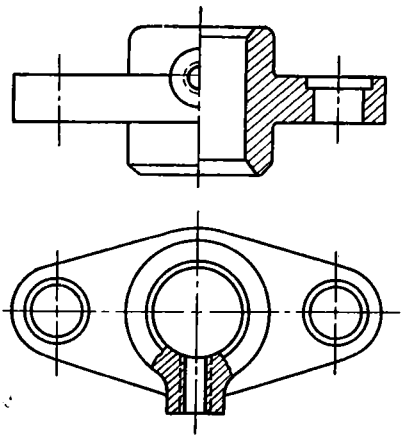


Fig. 19. Sectional view

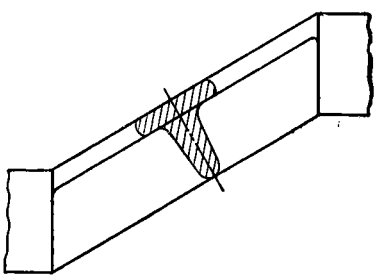


Fig. 18. Revolved section

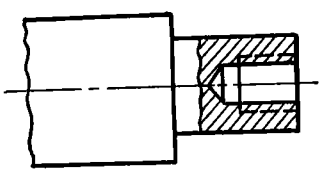


Fig. 20. Section of a part with a threaded hole

Depending on the direction of the cutting plane sections may be: vertical (vertical cutting plane), horizontal (horizontal cutting plane), oblique (cutting plane inclined to the horizontal).

Depending on the number of cutting planes sections may be simple or complex.

A recommended arrangement of sections in the drawing is as follows: draw vertical sections in the space provided for the front (main) view, vertical sections obtained by intersecting with a plane at right angles to the frontal plane of projection, and therefore parallel to the side-view plane, in the space for the left-hand view, and horizontal sections, in the space for the top view.

If the object is projected as a symmetrical figure, half the view (front, top or left-hand) may be combined with half of the corresponding section.

Simple sections are not indicated on drawings; complex sections and simple ones in which the edge of the cutting plane does not coincide with the axis of symmetry, are indicated by lines at the beginning, at breaks and at the end of the cutting plane edge; the lines are marked with capital letters of the Russian alphabet and the section is furnished with a caption.

7. Conventional Symbols Used in Drawings

To simplify the technique of drawing, conventional symbols have been accepted for a number of elements (Figs. 21 and 22).

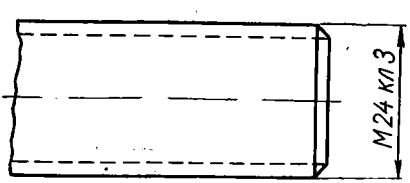


Fig. 21. Conventional symbols for a thread

The dimensions of a thread are indicated in drawings by writing the major diameter. In the case of metric threads the

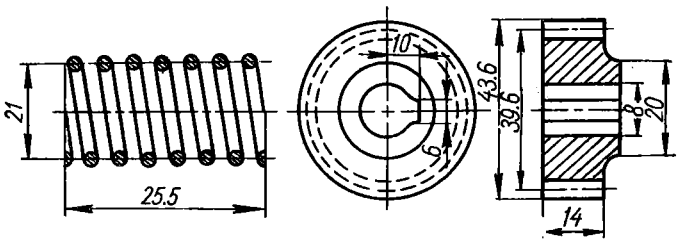


Fig. 22. Conventional symbols for helical spring and gear

figure indicating the outer diameter is preceded by the letter M.

The indication of a standard general-purpose thread on a drawing when several classes of accuracy have been standardized for the thread shown, should include the thread symbol and a symbol indicating the thread accuracy class (кл). For instance, M24×кл1, M16×кл1.

8. Gearing Diagrams

A gearing diagram is a drawing in conventional symbols showing the sequential connections between the separate parts of a machine, transmitting motion from the motor to its various units and to its working member. Conventional symbols are used on the gearing diagram to show the connections of the individual parts, the means of transmitting motion and the mutual arrangement of the parts.

Fig. 23 shows the conventional symbols used to indicate the main units in gearing diagrams.

9. Freehand Sketches

To facilitate the drawing of parts, or as a substitute for drawings (in the case of the simplest parts) preliminary sketches of the part are sometimes made by hand (without drafting instruments) "from life". Such graphical representations are called freehand sketches and often serve as the primary material for making the clean drawing.

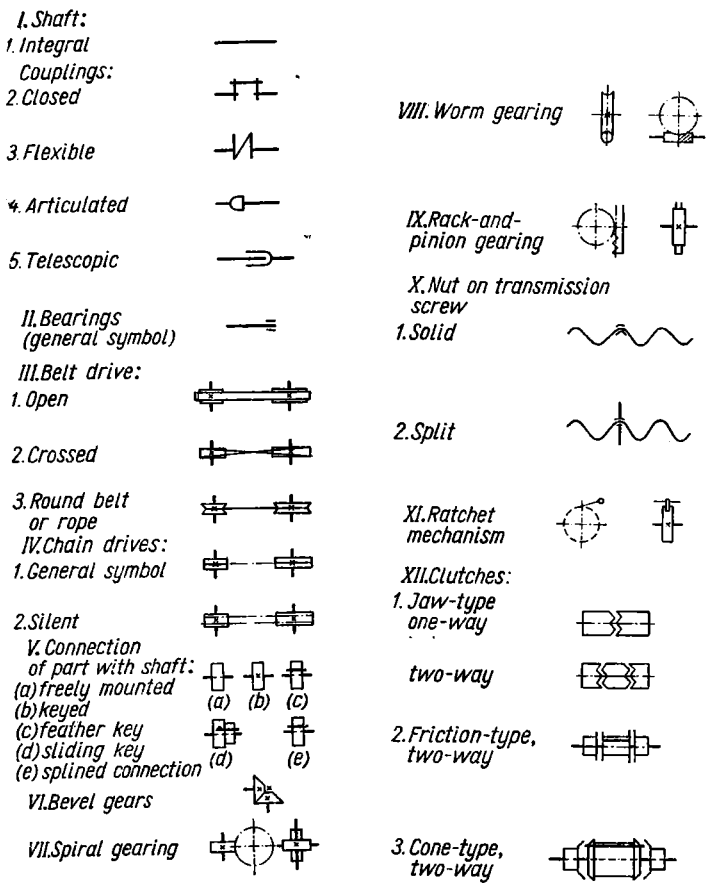


Fig. 23. Conventional symbols for gearing diagrams

Freehand sketches are made according to rules established by GOST for mechanical drawings.

The sizes of the part and its elements in the sketch should be approximately in the same proportion as in reality.

The number of projections in a freehand sketch (as well as in a drawing) should be the least possible. After making the sketch the object should be measured and its dimensions indicated on the sketch.

It is advisable to make freehand sketches on squared paper in pencil, using a compass only to draw circles or arcs.

The title on a freehand sketch should be executed by hand.

Before starting to draw the sketch decide on its scale and the number of views to be drawn, then draw the centre lines for each view, lay off the principal (largest) dimensions, and block in the outline of each view in light lines.

10. Assembly Drawings

Drawings which depict several mated parts are called *assembly drawings.*

An assembly drawing gives an idea of the construction of each of the parts of the unit, as well as of the unit itself.

The assembly drawing shows the correct relative positions of the parts, the unit as a whole, and the method by which they are joined.

Assembly drawings are drawn in orthographic projections.

The assembly drawing should contain a list, or "bill of material" covering all the parts making up the unit. The bill of material is a table indicating: the part number, name, quantity required and material.

When reading an assembly drawing, start by ascertaining what is shown in it, its specific features, then find out which views and sections are given, glance over the main dimensions and read all the inscriptions.

After this determine the shape and size of the parts by finding their projections on the assembly drawing.

To facilitate reading and assembly, the number of each part in the assembly drawing is indicated under a short line or inside a circle with a leader pointing to the part. When making assembly drawings of complex machines, besides the assembly drawing of the whole machine, drawings are made of some of its separate elements—mechanisms or units, as they are called. In assembly drawings three views of the machine are usually shown. Only the dimensions needed for assembling the parts and the principal dimensions of the unit or machine are indicated here; dimensions of parts are not shown in assembly drawings. Making the separate drawings of these parts after determining their shape and size from the assembly drawing, is called *detail drawing.*

CHAPTER THREE

ELEMENTS OF ENGINEERING MECHANICS

11. Motion

A body may be at rest or in motion. A body is said to be in motion if it changes its position with respect to other bodies in time.

In moving through space a body describes a line which is called the *trajectory of motion* of the body.

The motion of a body may remain constant or become faster or slower, and therefore we distinguish between uniform and nonuniform motion.

The motion of a body is said to be *uniform* if the distance it covers in equal time intervals is always the same, and *nonuniform* if the distance covered is not always the same.

We must distinguish between motion of translation and rotary motion. The motion of a body wherein all its points describe equal and parallel trajectories is called *motion of translation.* Fig. 24 illustrates the translatory motion of a rod *AB.*

Motion wherein all the points of a body move through parallel planes along circles whose centres lie on a single straight line (referred to as the axis of rotation) is *rotary.* The rotary motion of a disk is shown in Fig. 25.

Uniform motion of a body along a straight line is called *uniform rectilinear* motion. The *velocity of uniform motion* is the path covered by a body per unit of time. The unit of velocity accepted by the international system for measuring physical units* is the velocity whereby a path of one metre is covered in one second. Other commonly used units of

* In October, 1960, the 11th General Conference on Weights and Measures accepted the International System of Units. This universal system of units has been approved in the U.S.S.R. (GOST 9867-61).

velocity are: one centimetre per second and one kilometre per hour.

The velocity of uniform rectilinear motion is constant both in value and direction.

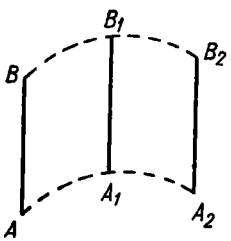


Fig. 24. Motion of translation of a rod AB. The points A and B describe identical trajectories

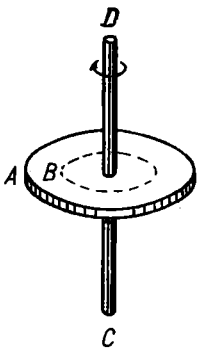


Fig. 25. Rotary motion of a disk. The points A and B describe circles of different circumference

Motion at a variable velocity is *nonuniform* or *variable* motion; the speed of such a motion is usually characterized by the average velocity over a definite time interval.

The *average velocity of nonuniform motion* is the velocity of a uniform motion by which the same path could have been covered in the same time as by the nonuniform motion in question.

Motion, the velocity of which changes by the same value over equal intervals of time, is called *uniformly variable.*

Uniformly variable motion may be uniformly accelerated or uniformly retarded. Uniformly variable motion is characterized by the speed at which the velocity changes, or the acceleration. The *acceleration of a motion* is the value by which the velocity changes per unit time; the unit of acceleration is the acceleration of a uniform motion during which the velocity changes each second by one metre per econd (1 m/s).

12. Force and Mass

A force is the cause of a change in the state of rest or motion of a body. A force may cause or stop a motion, retard or accelerate it and change its direction.

The force with which a body is attracted by the earth is known as the *force of gravity* or the *weight* of the body.

The quantity of matter in a body is called its *mass*. The weight of a body is proportional to its mass.

The basic unit of force is the newton, this being a force which will cause an acceleration of 1 m/s^2 in a mass of 1 kg at rest.

One kilogram-force is the force that imparts an acceleration of 9.80665 m/s^2 to 1 kg of mass at rest.

The unit of mass is the kilogram, which is the mass of the international prototype kilogram.

13. Equilibrium of a Body on Which Forces are Acting

Any magnitude which, besides a numerical value, has a definite direction in space, is called a *vector*. In drawings and diagrams vectorial values are denoted by arrows. The length of the arrow denotes the numerical value of the vector with reference to the scale to which it is drawn, and its direction is the direction of the vector. Being a vector, a force is characterized by its value, direction and point of application.

The point of application of a force acting on a rigid body may be removed to any point of the body, lying on the line of action of the force; this does not change the action of the force on the body. A body is in equilibrium if the forces acting on it balance each other. For instance, if a force F_1 is acting on a body (Fig. 26), then to keep the latter in equilibrium, a force F_2 must be applied to it, equal in value to the force F_1 and acting along the same line of action, but in the opposite direction.

If several unbalanced forces are acting on a body, it will move in a definite direction at a definite acceleration. The single force which could cause the same acceleration of

the body both in value and direction, as all the forces acting on it together, is called the *resultant of these forces.* Forces whose combined action is the same as that of the resultant are known as *component forces.*

Thus, to bring a body on which several individual forces are acting simultaneously to equilibrium, find their resultant and apply to the body a force equal to the resultant in

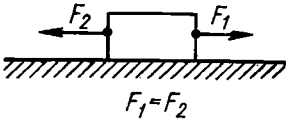


Fig. 26. A body is in equilibrium if two equal forces are acting on it along the same line in opposite directions

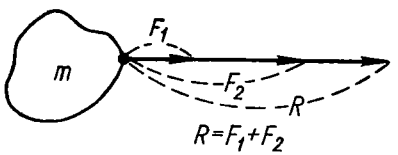


Fig. 27. The resultant of two forces acting along the same straight line in the same direction equals their sum and acts in the same direction

value, but opposite in direction (balancing force); the force thus applied must act along the same line as the resultant.

The determination of the value and direction of the resultant from its components is known as *composition* of the forces.

To simplify the addition of forces acting along the same straight line (their points of application may be shifted) it may be considered that the forces to be added are applied to the same point; the forces may be acting in the same direction or in opposite ones.

In the former case the resultant of the two forces applied to the same point and acting in the same direction along the same line equals their sum, is applied to the same point and acts in the same direction (Fig. 27). For example, if we suspend two weights of 5 kg each from the hook of a spring balance, the indicator will show 10 kg, i.e., in this case the resultant of the two 5-kg forces will be 10 kg. In the latter case (Fig. 28) the resultant of the two forces applied to the same point and acting along the same straight line in opposite directions is equal to their difference and acts in the direction of the larger force.

14. Composition and Resolution of Forces

Composition of Forces Acting at an Angle to Each Other. The resultant of two forces applied to one point and acting at an angle to each other is applied to the same point, and

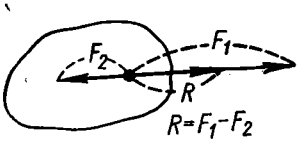


Fig. 28. The resultant of two forces acting along the same straight line in opposite directions equals their difference and acts in the direction of the larger force

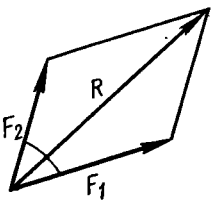


Fig. 29. Diagram showing the composition of forces acting at an angle to each other

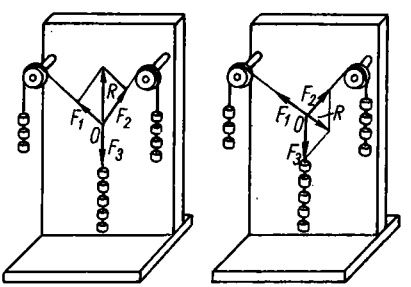


Fig. 30. Composition of forces acting at an angle to each other

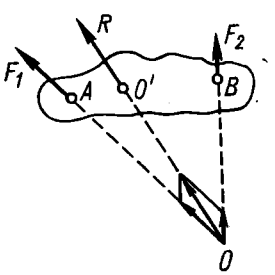


Fig. 31. Composition of forces applied to different points of a body

is represented in magnitude and direction by the diagonal of the parallelogram constructed on the forces as sides (Fig. 29).

The above is known as the *force parallelogram rule.* This rule can be explained experimentally by means of the apparatus shown in Fig. 30. The magnitude of the resultant of the two forces at an angle to each other is found by measuring the diagonal of the parallelogram of forces.

If the two forces acting on the body are at an angle to each other, lie in the same plane and are applied to points A and B of the body (Fig. 31) their resultant can be found by removing the points of application of the forces to the intersection of their lines of action, building the parallelogram of forces at this point and determining the magnitude and

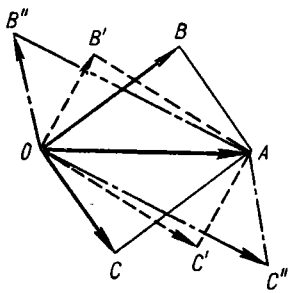


Fig. 32. Methods of resolving a given force into two components at an angle to each other

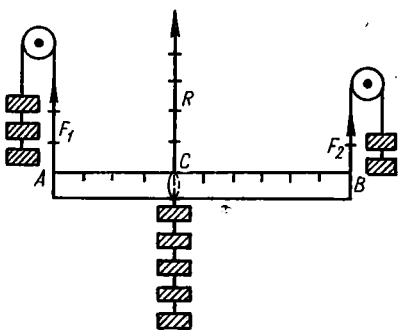


Fig. 33. Determination of the resultant of two parallel forces acting in the same direction

direction of the resultant. Then the point of application of the resultant can be moved to any point of the body that lies on the line of action of the resultant.

When determining the resultant of several forces applied to one point and acting at angles to one another, first find the resultant of any two forces, then that of their resultant and a third force, etc. The resultant of the last force and the resultant of all the rest is the resultant of all the forces.

Resolution of Forces into Two Components at an Angle to Each Other. To resolve a force into two components means to replace it by two forces which together cause the same action as the single force they have replaced.

In this case the vector of the force which is to be resolved into two components at an angle to each other is regarded as the diagonal of the parallelogram of the component forces, and the problem reduces to the construction of a parallelogram, given its diagonal.

This problem has an infinite number of solutions; to obtain a definite solution it is necessary to know the lines of action of the component forces.

Fig. 32 shows the solution of this problem. Draw lines from the end of the vector OA (point A) parallel to the given lines of action of the component forces and extend them until they intersect these lines at B and C. OB and OC are the component forces along the given directions.

Composition of Parallel Forces. To make clear the composition of parallel forces acting in the same direction consider the following example. Rule AB (Fig. 33) is suspended by cords which are passed over pulleys. Three equal weights are fastened to the free end of one of the cords, and two to the other.

To balance the action of these weights the loop of a cord holding five such weights has to be set at point C of the rule, closer to A, the end of the rule to which the heavier weight is fastened. By measuring the position of C we can establish that the resultant of two parallel forces acting in the same direction equals their sum, acts in the same direction and is applied to a point dividing the distance between the points of application of the forces into parts inversely proportional to these forces.

15. Centre of Gravity and Equilibrium

Any body consists of particles, and the force of gravity acts on each particle. The forces of gravity acting on the particles of a body are parallel. The weight of the body is the resultant of the forces of gravity of its particles. The point of application of the resultant of the forces of gravity acting on the individual particles of the boly is called its *centre of gravity*.

Equilibrium is said to be *stable* if the body tends to return spontaneously to its original position after being slightly displaced from it. Stable equilibrium is observed when the centre of gravity of the body is in the lowest possible position for the given conditions. If we stand a pencil up on a desk and give it a little push it will fall down. But if the pencil

is lying down it cannot be put into a more stable position. This is its most stable position, because its centre of gravity is in its lowest possible position.

16. Moment of a Force

Some of the parts of machines can have only rotary motion in operation.

A body may rotate about an axis in one of two opposite directions.

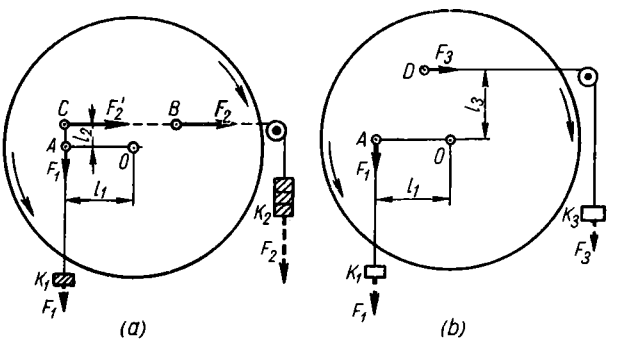


Fig. 34. Experiment demonstrating that rotating action is determined by the product of the force by its arm length:
(*a*) first arrangement of loads on disk, (*b*) second arrangement

The rotary action of two forces is equal in magnitude if the body remains in equilibrium when they act simultaneously in opposite directions.

The above will be clear from the following example (Fig. 34). Suppose we have a disk with several holes in it, which can rotate about its axis O (Fig. 34*a*).

Insert a pin in hole A and tie a cord to it; attach a weight K_1 to the other end of the cord. The weight K_1 will stretch the cord with the force F_1 making the disk rotate counterclockwise. Then insert another pin in hole B and tie a piece of cord to it; attach a weight K_2 to the other end of this cord. The weight K_2 will cause a tension of F_2 in the cord, making the disk rotate clockwise, i.e., in the direction opposite

to the rotation caused by the force F_1. Now select the weight K_2 so that the action of the forces F_1 and F_2 is balanced.

Then move the pin from hole B to hole C on the line of action of the force F_2; this will not disturb the equilibrium of the disk. The distance l_2 from the axis of rotation to the lines along which F_2 is acting in both cases has not changed. If we increase this distance to l_3 (Fig. 34*b*), the equilibrium of the disk will be disturbed and it will begin to rotate clockwise. But if the weight is now decreased to a definite magnitude equilibrium will be restored. Thus, the rotating action of a force depends not only on its magnitude, but on the shortest distance from the axis of rotation to its line of action as well. This distance is called the *arm of the force.*

The magnitude equal to the product of the magnitude of a force and its arm is known as the moment of the force. The moment of a force is denoted by M, and $M = F \times l$.

If $l = 0$, the moment of the force is also zero.

The moment of a force rotating a body clockwise is considered positive, and that rotating a body counterclockwise, negative.

17. Fixed Joints

PERMANENT JOINTS

Permanent joints are joints that cannot be taken apart, i.e., disassembled, without deforming or destroying the fastenings and sometimes the mated parts as well. Permanent joints include certain interference fits, welds, riveted joints, etc.

Interference Fits. For such fits the hole in one of the components is made smaller than the part of the other component which is to be inserted in the hole. The difference in these sizes is called the *interference* or *negative allowance.*

In this case one component can be inserted in the other only under pressure. A fit of this kind is assembled with a press (drive fit). If the interference is large the part with the hole is heated and the other part is press-fitted into it cold (shrink fit).

Disassembly of such connections involves destruction of the components or at least of the mating surfaces.

Welded Joints. Welding is a method of joining metals by the cohesion of their atoms.

Welding is one of the most up-to-date methods of making permanent joints.

The use of welding effects a considerable saving of metal.

Three chief types of welding are distinguished:

(1) fusion welding;

(2) solid-phase pressure welding;

(3) cold welding.

Fusion welding includes: manual metal-arc welding, automatic submerged-arc welding, gas-shielded arc welding and gas welding.

Solid-phase pressure welding includes: flash and upset butt welding, pressure induction welding, pressure-arc welding and gas-pressure welding.

Cold welding includes cold pressure welding and ultrasonic welding.

The parts of contractor's machinery are usually joined by arc and gas welding procedures.

In arc welding an electric arc is struck between the electrode connected to one of the terminals of the source of welding current, and the metal being welded, to which the second terminal of the current source is connected. The intense heat generated by the arc (its temperature is as high as 3,000 to 4,000°C) melts the metal. During the entire process the end of the electrode remains in the molten state and liquid metal drops from it into the weld. Here the metal of the electrode mixes with the molten metal of the work.

The arc generates heat over a small distance, forming a depression in the metal called the weld pool or crater.

The distance between the end of the electrode and the bottom of the crater is called the arc length. For good welding the arc length should be as small as possible, not longer than 1 to 4 mm. The longer the arc, the greater the path the molten metal of the electrode has to pass through the air, and hence the more oxygen and nitrogen it absorbs. These gases impair the mechanical properties of the metal in the joint, in particular they lower its tensile and impact strength.

The principal condition for good metal-arc welding is complete fusion of the metal of the work and that of the electrode so that the metal of the seam retains all the phys-

ical, chemical and mechanical properties of the parent metal.

Gas welding is done by melting the metal of the pieces being welded and of the welding rod. The heat needed for welding is supplied by burning a mixture of oxygen and various combustible gases, viz., acetylene, methane, hydrogen, gasoline or kerosene vapour, etc. On burning, an acetylene-oxygen mixture produces a flame with a temperature of

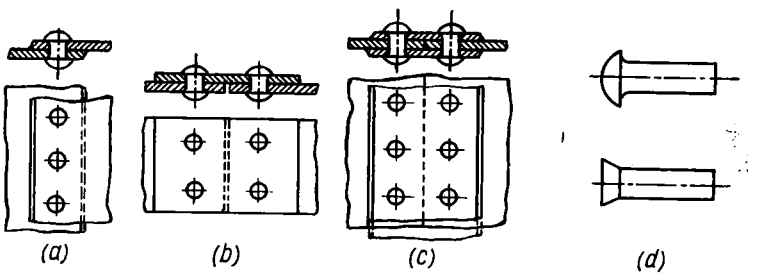


Fig. 35. Riveted seams and rivets:
(*a*) single-riveted lap seam, (*b*) one-strap seam, (*c*) two-strap seam, (*d*) button- and countersunk-head rivets

about 3,000°C. Playing on the ends of the parts to be welded, the flame quickly heats them to the melting point, simultaneously melting the welding rod.

Gas welding is done as follows. The welding rod is moved in a straight line along the joint, followed by the welding torch with the flame directed to the end of the rod and to the edges of the pieces being welded. The welder waves the torch slightly from side to side across the weld, heating the edges alternately to form the molten pool.

The gas for gas welding is supplied through regulators, these being devices for reducing the pressure at which the oxygen and acetylene are stored in cylinders to the working pressure.

Riveted Joints. These joints are used for connecting steel sheets, plates and shapes. The rivets are arranged in the joint in a definite order; the driven rivets together with the united parts make the riveted seam.

According to their purpose, riveted seams may be strong (joints of frames, booms, etc.), pressure fluid-tight (seams

of air collectors, steam boilers and other reservoirs operating under pressure), or fluid-tight (seams of tanks, vats, etc.).

Riveted seams may be lapped (Fig. 35*a*), one-strap (Fig. 35*b*) or two-strap (Fig. 35*c*). With respect to the number of rows of rivets on each of the joined components riveted seams may be single-, double- or triple-riveted.

The most common types of rivets with button and countersunk heads are shown in Fig. 35*d*. Rivets are made of steel or nonferrous metals.

Depending on the requirements made to the riveted seam, the holes for the rivets may be punched and reamed, or drilled. The hole diameter should be slightly larger than the rivet diameter; the rivet hole is countersunk to accommodate the fillet on the rivet shank just below the head.

The components are placed on one another with the holes coinciding and are temporarily held together by tack bolts; then the rivet is inserted in the aligned holes. The rivet shank should project above the surface of the component to allow for the formation of the closing head when riveting.

Riveting may be done without forming a closing head above the surface of the riveted component (countersunk riveting). In this case in driving the rivet the metal is forced to fill the countersunk part of the hole.

SEPARABLE JOINTS

Separable joints are joints that can be taken apart without destroying the fastenings. These include bolted and screw joints, cottered and key joints and certain types of interference and transition fits.

Bolted joints are fixed separable joints whereby the elements are fastened together by bolts.

A *bolt* is a fastening having the shape of a rod with a screw thread at one end and a hexagonal (Fig. 36*a*), square (Fig. 36*b*), button (Fig. 36*c*) or flat countersunk (Fig. 36*d*) head at the other.

Bolts may be general-purpose or special.

General-purpose bolts fall into three types: finished bolts which are machined from structural hexagonal steel stock; semifinished, made by cold heading followed by threading

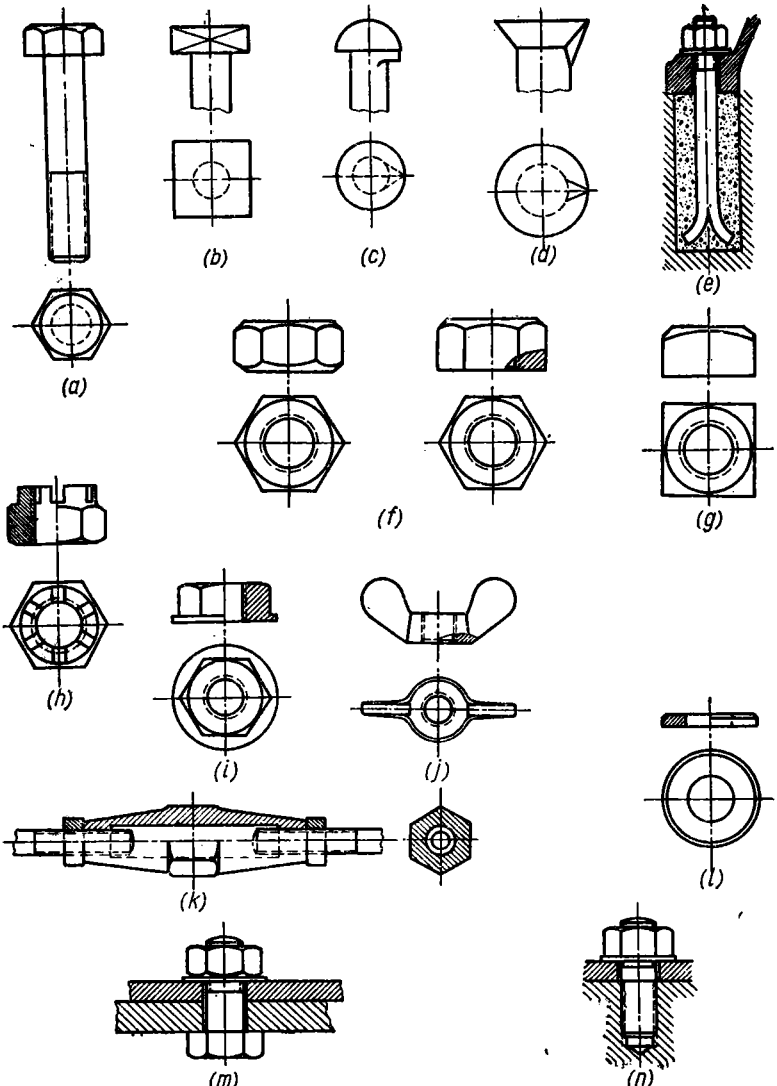


Fig. 36. Bolts, nuts, washers and bolted joints:
(*a*) hexagonal headed bolt, (*b*) square headed bolt, (*c*) button headed bolt, (*d*) countersunk headed bolt, (*e*) foundation bolt, (*f*) hexagonal nut, single- and double-chamfered, (*g*) square nut, (*h*) castellated nut, (*i*) hexagonal collared nut, (*j*) winged nut, (*k*) turnbuckle, (*l*) washer, (*m*) bolted joint, (*n*) stud joint

and machining of the bearing surface of the head; and rough bolts made by cold heading or forging.

Finished and semifinished bolts are made of steel, grades Ст.2 to Ст.6; 35X, 40X, 40XH, etc.

Rough bolts are made of round carbon steel (Ст.3, steel 10, steel 15, etc.); the shank and head of rough bolts are not machined.

Special bolts include bolts with reduced or enlarged hexagonal or square heads, with button or countersunk heads, foundation bolts (Fig. 36*e*) for fastening machines to foundations, etc.

The *nut* is the part of the bolt fastening which is screwed on the threaded part of the bolt. Nuts may be hexagonal (Fig. 36*f*), square (Fig. 36*g*) or of other shapes.

Nuts may be general-purpose or special. The former fall into three types: finished, single- or double-chamfered (Fig. 36*f*), which are machined from hexagonal steel stock of exact dimensions; semifinished and rough nuts, cold headed from mild carbon steel.

Special nuts are made of special steels, cast iron or nonferrous alloys. Special-purpose nuts may be hexagonal and castellated (Fig. 36*h*), hexagonal collared (Fig. 36*i*), winged (Fig. 36*j*), turnbuckles (Fig. 36*k*), etc.

A *washer* (Fig. 36*l*) is a flat ring which is placed under the nut to protect the surface of the piece against damage when the nut is being screwed on and to increase the bearing surface of the nut.

Washers may be finished, or rough, the former being machined and chamfered and the latter stamped and unchamfered.

To make a bolt connection, place one of the pieces on the other so as to match the holes in them (Fig. 36*m*), insert the bolts in the matched holes, slip washers on them, and then screw on the nuts, using a wrench to tighten them.

A *stud* is a cylindrical rod (Fig. 36*n*) with screw threads on both ends. One end of the stud (the stud end) is screwed into a threaded hole in the main component and the other component is placed on the projecting end. A washer is slipped over the nut end of the stud projecting above the second component and then a nut is screwed on to make the joint.

Screw joints are separable and may be fixed or movable.

A *cap screw* is a rod with a head at one end. The head may have flats to accommodate a wrench or it may be slotted for a screw driver. The rod may be threaded over its entire length or over part of it. Various kinds of cap screws are shown in Fig. 37*a*.

Depending on their purpose, screws are divided into fastening and set screws.

Fig. 37*b* shows a fixed screw joint. The pieces joined have holes in them, one of which is threaded.

To make a screw joint the pieces are placed on one another so that the holes in them coincide; the screw is inserted through the unthreaded hole and screwed into the threaded one.

Cottered joints (Fig. 38) are fixed separable joints. They are made by inserting a tapered key or driving a cotter into the matched slots of the pieces being fastened together.

Cottered joints may be unstressed (Fig. 38*a*) or stressed (Fig. 38*b*); the former are used for unidirectional loads, and the latter for alternating loads. In the case of stressed joints the cotter is driven in under considerable force.

Key joints are separable joints made by means of keys (Fig. 39).

Key joints may be fixed or sliding.

Keys are used for fastening rotating or rocking parts to their shafts or axles. Keys are commonly made of carbon steel.

According to purpose keys fall into tapered and plain types; the former have a lengthwise taper of 1 : 1,000; the latter have no taper.

Taper keys provide a stressed joint made by driving them in or forcing the piece onto them under pressure; they may be sunk keys, flat keys, saddle keys, etc.

Sunk keys are used to transmit large torques on shafts 10 to 500 mm in diameter.

Flat keys are used for shafts from 20 to 230 mm in diameter.

The disadvantages of these two kinds of key joints are that they require the sinking of keyways (grooves) or the filing of flats on the shaft and allow the part to be fastened only at a definite place.

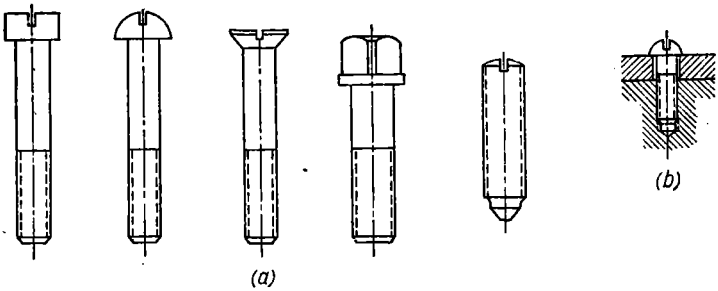


Fig. 37. Cap screws and screw joints:
(*a*) types of cap screws, (*b*) fixed screw joint

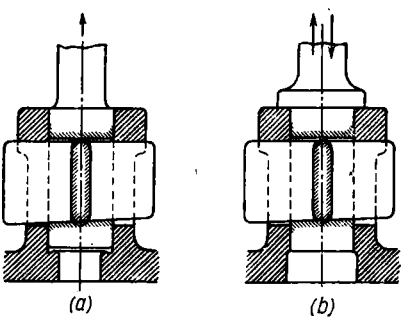


Fig. 38. Cottered joints:
(*a*) unstressed, (*b*) stressed

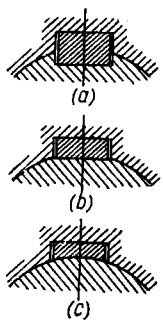


Fig. 39. Types of keys:
(*a*) sunk feather key, (*b*) taper key on flat, (*c*) saddle taper key

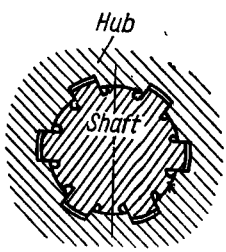


Fig. 40. Spline joint

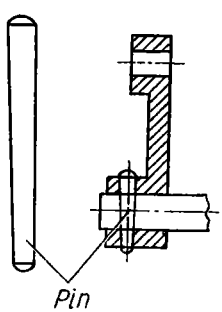


Fig. 41. Pinned joint

Saddle keys contact the cylindrical surface of the shaft; the piece is held on the shaft by the friction which arises between the key and the shaft when the key is driven in. Such keys are used on shafts from 20 to 150 mm in diameter. Saddle-key joints are free from the shortcomings of the first two types of key joints, but cannot be used for the transmission of large torques.

Feather keys permit axial movement of the part along the shaft on the key. Feather keys include plain sunk keys and screw-held keys.

Spline joints are multiple-spline fittings (Fig. 40) and may be sliding or fixed. In these joints the splines are integral with the shaft. Multiple-spline fittings can transmit larger loads than single-key joints. They have other advantages as well: they exclude the possibility of the key being wrenched out of the keyway in operation, are less liable to wear, provide more accurate joining of the parts, etc.

Pinned joints are fixed separable joints (Fig. 41). They are made by driving a cylindrical or taper pin into matched holes in the pieces being connected.

18. Movable Joints

SHAFTS AND AXLES

Rotating machine parts (pulleys, gears, etc.) are seated on shafts or axles which run in supports (bearings or thrust bearings). Axles and shafts may be horizontal, inclined or vertical.

These parts are made mainly of carbon and alloy steels by open- or closed-die forging; sometimes shafts are cast from steel or high-strength cast iron.

Axle and shaft blanks are machined. If they form part of critical units of machines they are also heat treated.

Axles. Axles only support the parts seated on them, i.e., are subject to bending stresses. Axles may be *stationary* (when the parts are freely mounted and rotate on them) and *rotating* (when they rotate in bearings together with the parts on them).

Shafts. Shafts not only support the parts seated on them, but also transmit torque loads from one part of the machine

to another; thus, in service shafts are subject to bending and torsion stresses.

The following types of shafts are distinguished depending on the loads they are subject to: heavy-duty, light-duty and special-duty; depending on the number of supports—two-support and multiple-support; depending on the shape of their surface—plain and stepped; depending on their axis—straight shafts and crankshafts.

Heavy-duty (main) shafts take the load directly from the prime mover.

Special-duty shafts include camshafts, hollow shafts, etc.

Stepped shafts have shoulders, grooves, etc.

Straight shafts are used in machines when rotation has to be transmitted from one part to another, for instance, from one toothed gear to another.

Crankshafts are used when rotary motion has to be converted into reciprocating motion. These shafts may be of the overhung (Fig. 42*a*) or central (Fig. 42*b*) type. Overhung cranks are usually shrunk-fit on the shaft and fixed with cotters.

Overhung crankshafts may have one or more crankpins arranged at various angles.

Central crankshafts may have one, two, four or more crankpins arranged between the shaft bearings at 45°, 60°, 90°, 120°, 180°.

Eccentric shafts are made by fitting a circular disk with an eccentric hole on a straight shaft, or by machining a special blank.

The parts of shafts and rotating axles that are supported by and revolve in bearings are called *journals* (Fig. 43).

Journals subjected to transverse loads fall into end journals and neck journals.

As the name implies, an *end journal* (Fig. 43*a*, *b*, *c*, *d*) is one located at the end of the shaft or axle. End journals may be cylindrical, conical or spherical. Spherical end journals, more commonly known as ball pivots, are used when the shaft is designed to pivot into various positions.

A *neck journal* (Fig. 43*e*, *f*) is one situated in the middle part of a shaft or axle.

A *thrust* or *vertical journal* is one subjected to axial load. Thrust journals may be at the top, at the bottom or in the

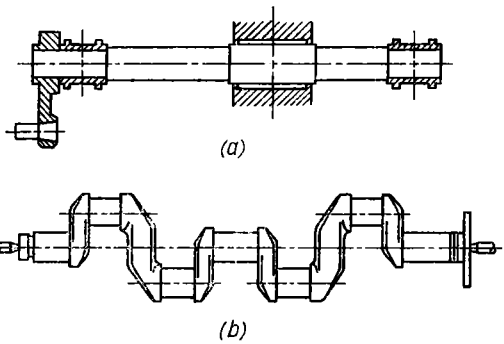


Fig. 42. Crankshafts:
(*a*) overhung, (*b*) central

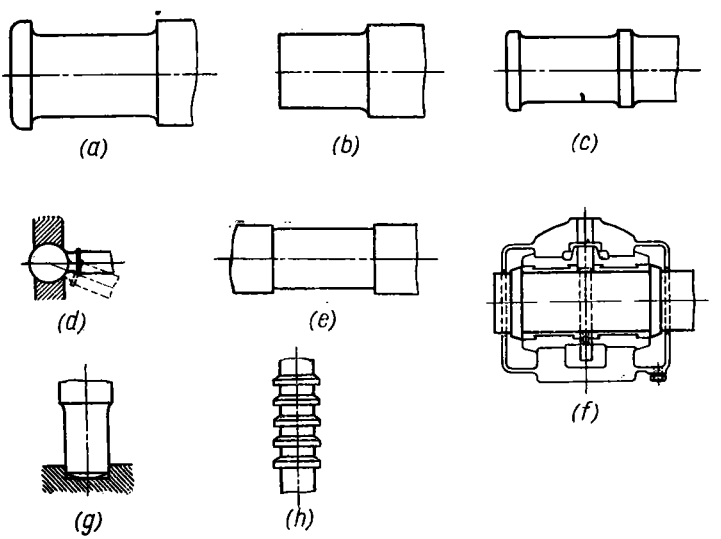


Fig. 43. Journals:
(*a*) cylindrical end journal with shoulders, (*b*) ditto, with one shoulder, (*c*) ditto, with swell and collar, (*d*) spherical end journal (ball pivot), (*e*) neck journal with swells, (*f*) neck journal with collars, (*g*) cylindrical thrust bearing, (*h*) collar journal

middle of the shaft. Bottom thrust journals, called toes or pivot-journals, are cylindrical in shape (Fig. 43*g*); top and middle thrust journals, known as collar journals, have a number of annular collars (Fig. 43*h*).

To keep a shaft with a cylindrical end or neck journal from moving axially, these parts are made with one or two shoulders. The transition (smooth curve) from the shaft to the journal is called the *fillet.* If the diameter of the journal is the same as that of the shaft the journal is furnished with swells or collars.

If the shaft diameter is the same over its entire length (plain shafts) any part of the shaft may serve as a neck journal, and in this case the shaft is located in the bearing by means of split or solid loose collars.

The working surface of a cylindrical solid thrust journal is its end; a collar journal rests with the bearing faces of its collars on the supports.

SHAFT AND AXLE BEARINGS

Supports in which end and neck journals run are called bearings, and for thrust journals—thrust bearings (end-thrust or collar-thrust bearings), step bearings, etc.

Bearings may be of two types: plain (sleeve) bearings or antifriction (roller and ball) bearings.

In plain bearings the journal rotates supported by the bearing surface which is coated with a film of lubricant; in this case friction is of the sliding type.

There must be a clearance between the journal and bearing surfaces.

In antifriction bearings the supported part of the shaft or axle has a ring fitted on it which rolls on the balls or rollers of the bearing; this entails rolling friction.

In antifriction bearings the starting torque, running friction and lubricant consumption are lower than in plain bearings.

Plain bearings may be of the following types: bores and simple bush bearings, flange bearings, pillow blocks and ring-oiled bearings.

Bores and simple bush bearings (Fig. 44) are holes bored in the frame of the machine, with or without a press-fitted

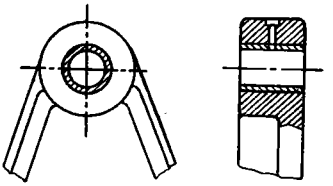


Fig. 44. Simple bush bearing

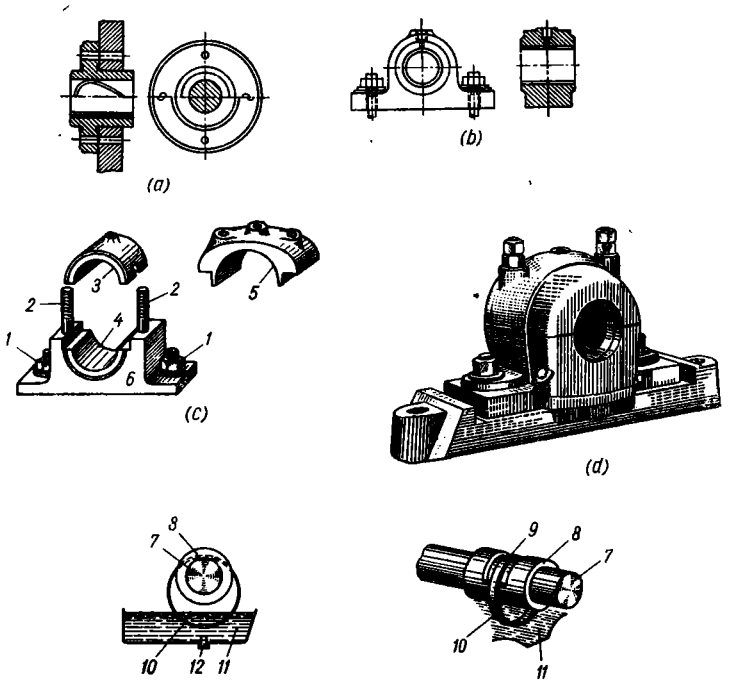


Fig. 45. Plain bearings:

(*a*) flange bearing, (*b*) solid pillow block, (*c*) split pillow block, (*d*) ring-oiled bearing, (*e*) oil ring lubrication; *1* and *2*—studs, *3*—upper insert, *4*—lower insert, *5*—cap, *6*—base, *7*—shaft, *8*—shell, *9*—slot, *10*—oil ring, *11*—oil, *12*—drain hole

bushing, and are the simplest type of plain bearing.

Flange bearings (Fig. 45*a*) and *solid pillow blocks* (Fig. 45*b*) are used for shafts rotating at low speeds. A bushing is often inserted in the hole of the cast-iron bearing and is fixed against rotation with the shaft; worn bushings are replaced.

Split pillow blocks or *bearings* (Fig. 45*c*) are made of cast iron. They consist of a base *6*, cap *5*, lower insert *4*, upper insert *3*; the cap is fastened by studs *2* with nuts, and the base is fastened by bolts *1* with nuts. To keep the inserts from rotating with the shaft they are made with lugs which locate them in the base.

Bushings and inserts are important parts in plain bearings; depending on their size and service duty they may be made of cast iron for small loads; of bronze for high loads and diameters less than 100 mm; of cast iron or bronze with a bearing alloy lining for diameters up to 150 mm; of cast steel with bearing alloy lining for diameters larger than 200 mm; and also of plasticized wood, plastics and rubber in special cases.

In all cases the bearing should be designed so that most of the wear is confined to the bushing or insert, since it is more easily replaced than the shaft.

Shims are inserted between the halves of the insert, and in the course of hole wear these shims are removed one by one to restore the size of the clearance between the shaft journal and the bearing.

In the above-described bearings lubricant is introduced through a hole in the cap, into which a lubricating appliance is screwed. Wick-feed oilers (Fig. 46*a*) are used for oils, and grease cups (Fig. 46*b*) or pressure grease fittings (Fig. 46*c*) for greases.

A grease cup consists of two parts, the body and bonnet or cap. The body is screwed into the hole in the bearing and the bonnet is packed with grease and screwed onto the body. When the bonnet is screwed down it forces the grease out on the friction surfaces. The bonnet should be screwed down one or two turns periodically.

Pressure grease fittings are used for forcing lubricant into the bearing. The fitting consists of a body, a ball and a spring.

Ring-oiled bearings (see Fig. 45*d*) have an oil reservoir arranged below the shell in the bearing base. These bearings may have movable or fixed bearing shells.

Ring-oiled bearings are of the following construction: the shaft *7* rotates in the bearing shell *8* which has a slot *9* at the top for keeping oil ring *10* in the middle of the bearing. The top part of the ring rests on the shaft, and the

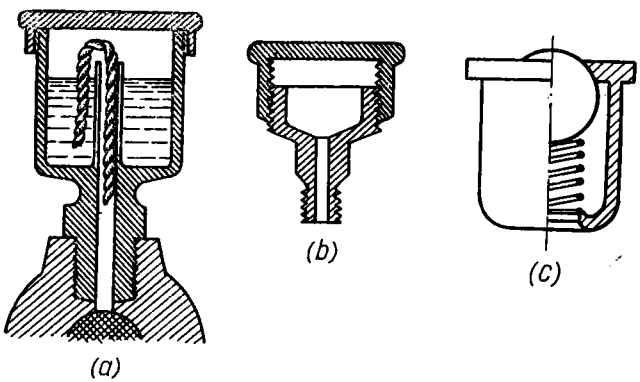


Fig. 46. Lubricators:
(*a*) wick-feed oiler, (*b*) grease cup, (*c*) pressure grease fitting

bottom part is immersed in the oil *11* in the reservoir. When the shaft rotates the ring also rotates carrying drops of oil to the shaft surface. Used oil is drained through hole *12*.

Antifriction bearings may be ball or roller bearings; depending on the type of load acting on them these bearings fall into three groups: radial, which support loads acting at right angles to the shaft or axle; thrust bearings, used to carry axial loads acting along the shaft or axle, and radial-thrust, or angular-contact, which support both types of loads simultaneously.

All antifriction bearings are manufactured in three series: light (Л), medium (С) and heavy (Т); besides, all bearings of this type are made with or without cages, or retainers. In the former the balls or rollers are arranged in cages to keep them apart and evenly distributed around the circumference; in the latter the balls and rollers are not thus separated.

A *radial ball bearing* (Fig. 47*a*) consists of an outer ring *1*, inner ring *2* with races (grooves) and balls *4*. The balls are retained in cages *3*. One of the rings, more frequently the

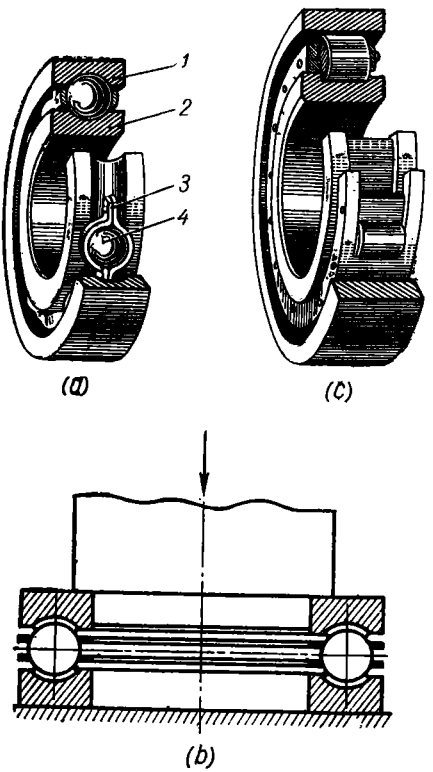


Fig. 47. Antifriction bearings:
(*a*) single-row radial ball bearing, (*b*) single-row thrust bearing, (*c*) single-row roller bearing; *1*—outer ring, *2*—inner ring, *3*—cages, *4*—balls

inner one, is fitted on shaft and rotates together with it; the other is fixed in the bearing housing or bore.

Balls are made of round high-carbon chromium steel bar stock, and races, from seamless tubes of the same steel.

Radial ball bearings may be single-row or double-row.

A *thrust ball bearing* (Fig. 47*b*) also consists of balls contained in cages, or retainers, and rings. The shaft bears with its shoulder on one ring and rotates together with it. Thrust bearings may be single- or double-direction in design.

Roller bearings (Fig. 47*c*) differ from ball bearings in that the rollers contact the races along a straight line, whereas balls contact them at one point; the friction in these barings is several times as high as in ball bearings.

Roller bearings are available with six kinds of rollers: long cylindrical solid rollers, hollow and helically wound flexible rollers; short cylindrical, tapered and barrel-shaped rollers.

Tapered rollers are used in thrust bearings; barrel-shaped rollers are employed in self-aligning bearings; wound flexible rollers, for impact loads.

Hollow rollers are mounted on pins riveted at each end to rings.

The method of protecting support and thrust bearings against dust and dirt is selected depending on the design and purpose of the unit. In simple cases felt seals are used.

The use of protective seals and packings reduces the wear of the bearing, because they keep dust from getting between the working surfaces; they reduce friction and lubricant consumption as well.

19. Drives

Mechanical drives (transmissions) are mechanisms which serve to transmit power, change speeds, forces and kinds of motion. For example, motors may have different speeds of rotation than the machine should have. The speed of rotation of the machine has to be variable (adjustable). This is done by means of a drive. Motors (electric or internal combustion) produce rotary motion, as a rule, while the working parts of the machine often have a reciprocating motion; therefore, to convert the rotary motion of the motor into the reciprocating motion required by the operative unit, special drives are used. The machine is usually situated some distance away from the motor, and in such cases they are linked together by means of a drive.

Mechanical drives may transmit motion by positive engagement or by friction. The former type includes toothed gearing (with spur, helical or bevel gears), worm gearing (worm and worm wheel), chain drives (roller drive chain and sprockets). Friction drives include belt drives (two pulleys and an endless belt) and friction gearing (two rigid friction parts).

Any drive has a driving element—that which transmits the motion, and a driven element—to which motion is transmitted.

TOOTHED GEARING

Toothed gearing consists of mechanisms for transmitting rotation from a driving to a driven shaft by means of toothed gears or a worm and worm wheel.

Toothed gears have projections (teeth) and spaces around their circumference. When the driving gear rotates, the driven one is put into positive motion owing to the pressure exerted by the contacting teeth of the driving gear on those of the driven one.

The axes of the gears in a gear train may be parallel, intersecting or nonparallel and nonintersecting (crossed).

Transmissions between parallel shafts employ *spur*, *helical* or *double-helical* (herringbone) *gears* (Fig. 48).

Transmissions between intersecting shafts are achieved with *bevel gears* (bevel gearing), shown in Fig. 49.

If the shafts are both nonparallel and nonintersecting *spiral** *gears* (spiral gearing, Fig. 50*a*) or a *worm* and *worm wheel* (worm gearing, Fig. 50*b*) are used.

Spur and helical gearing enable transmission of large amounts of power; the power transmitted by bevel gearing is less; worm gearing is used for obtaining a large speed reduction.

Gear drives operating at peripheral speeds up to 0.5 m/s are classed as very low speed, from 0.5 to 3 m/s as low speed, from 3 to 15 m/s as medium speed, and over 15 m/s as high speed.

A toothed gear is characterized by three circles (Fig. 51): the outside circle bounding the tops of the teeth; the root

* When helical gears are used to drive nonparallel shafts, they are usually called spiral gears.—*Tr.*

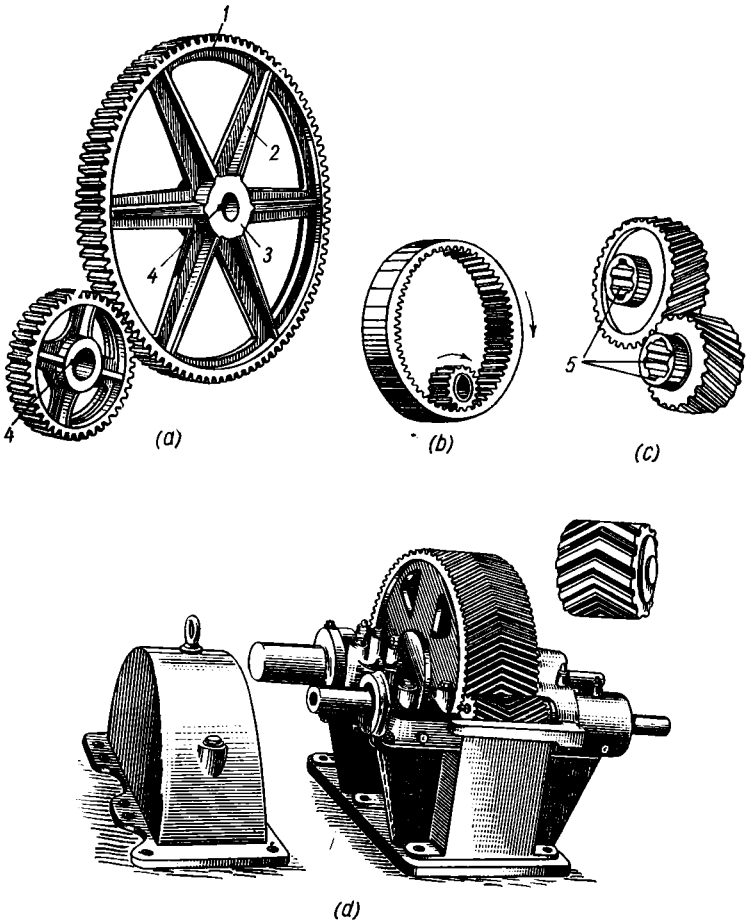


Fig. 48. Transmissions between parallel shafts with spur, helical and double-helical gears:

(*a*) external-contact spur gears, (*b*) internal-contact spur gears, (*c*) helical gears, (*d*) double-helical (herringbone) gears; *1*—rim, *2*—arms, *3*—hub, *4*—keyway, *5*—splined hole

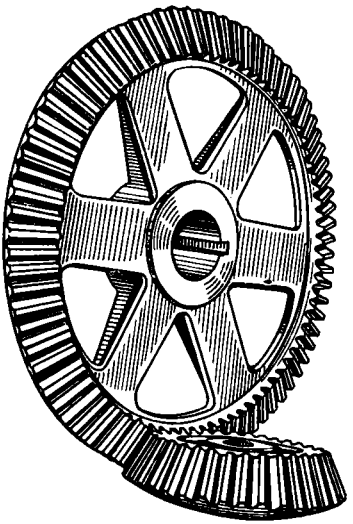


Fig. 49. Transmission between intersecting shafts with bevel gears (bevel gearing)

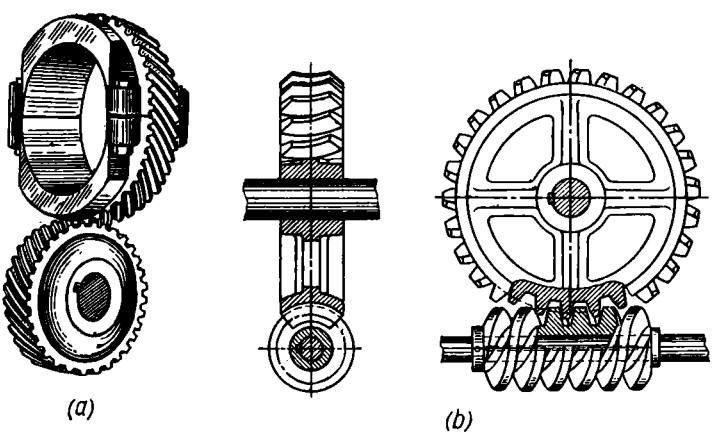


Fig. 50. Transmission between nonintersecting shafts at an angle to each other:
(a) with spiral gearing, (b) by means of worm and worm wheel (worm gearing)

circle passing through the bottoms of the tooth spaces, and the pitch circle which divides the tooth depth into two unequal parts, the upper part being called the addendum, and the lower, the dedendum.

The *tooth thickness* is the distance between the sides of the tooth measured along the pitch circle. The *space width* is the width of the space between two adjacent teeth measured along the pitch circle. The *circular pitch* of a gear is the

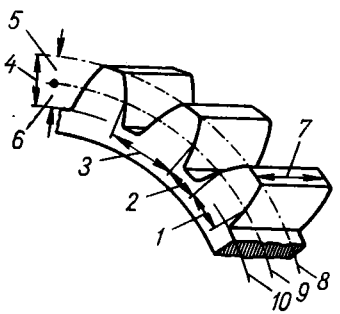


Fig. 51. Elements of a gear:
1—tooth thickness, *2*—space width, *3*—circular pitch, *4*—tooth depth, *5*—addendum, *6*—dedendum, *7*—face width, *8*—outside circle, *9*—pitch circle, *10*—root circle

distance between corresponding points of adjacent teeth on the pitch circle, or the sum of the tooth thickness and the space width. The distance between the ends of a tooth measured parallel to the shaft axis is called the *face width.*

Depending on the amount of power transmitted and the peripheral speed, gears may be iron, steel or bronze castings; they are also forged, drop-forged or welded from carbon or alloy steel; in some cases they are made of leather, plastics and other materials.

Gear teeth are cut in most cases with machine tools.

Most steel gears for modern machinery are hardened and tempered or casehardened, depending on the grade of steel and the purpose of the gears.

Gears less than 500 mm in diameter are made in the form of disks. Larger gears consist of a rim *1*, arms *2* and a hub *3* (see Fig. 48*a*).

Rims of cast gears may be flat or with one or two ribs on their inner surface.

Small gears may be made integral with their hubs (see Fig. 48*b*). Otherwise, the teeth may be on the shaft (pinion shafts).

If the face width of a cast gear is less than 1.5 times its diameter its rim is connected with the hub by means of a web with holes (openings) or arms of oval cross section; double webs or cross-, I- or H-section arms are used for large diameters.

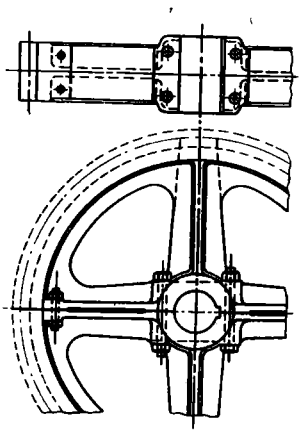


Fig. 52. Split gear

The hub should be provided with a keyway *4* or splined hole *5* for fixing the gear on the shaft.

Gears may be solid (see Fig. 48) or split (Fig. 52) or may be made in the form of a rim (see Fig. 48*a*, *b*).

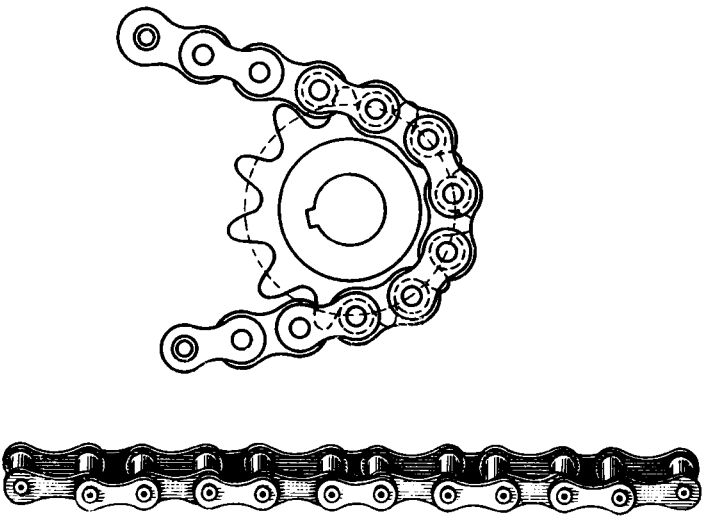
The method of manufacture and the accuracy class of gears are selected depending on the requirements they have to meet. There are four accuracy classes to which gears are made. The first class is the most accurate. The second class covers high-speed gearing involving peripheral speeds up to 15 m/s; the third, up to 8 m/s; the fourth class covers low-speed gearing having peripheral speeds of 3 m/s and less.

Gears for contractor's machinery are most often made to the third and fourth accuracy classes.

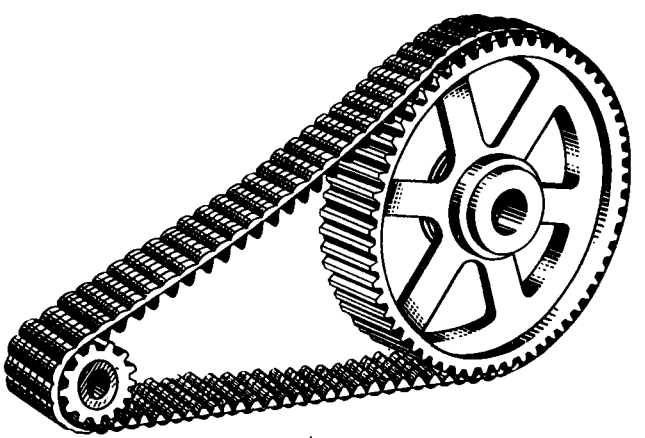
CHAIN DRIVES

A chain drive consists of driving and driven sprockets fixed on shafts and connected with an endless chain. Chain drives (Fig. 53) can be used to transmit motion from one shaft to another parallel shaft at a distance of up to 8 m. Chain drives can transmit power up to 5,000 hp at peripheral speeds up to 20 m/s.

During operation the projections (teeth) of the sprockets engage the spaces in the links of roller chains, or when a silent



(a)



(b)

Fig. 53. **Chain drive:**
(*a*) with stud chain, (*b*) with toothed chain

chain is used, its teeth engage the sprocket teeth, thus transmitting the motion.

The normal distance between shaft axes for chain drives should be 40 to 50 times the chain pitch, but not less than 1.5 times the diameter of the larger sprocket.

Sprockets are made as gray iron castings for chain speeds under 2 m/s, or steel castings for higher speeds. Idlers are used to tension the chain.

BELT DRIVES

Belt drives (Fig. 54) transmit motion by means of endless belts and are employed when the distance between the shafts involved is considerable.

Such drives can transmit up to 2,000 hp. Most commonly, up to 50 hp is transmitted at speeds from 5 to 25 m/s.

Belt drives of contractor's machinery consist of driving and driven pulleys fixed on shafts, with an endless flat belt or one or more endless V-belts running over them.

A drive belt has a driving (tight) and a following (slack) side.

The motion is transmitted due to the friction developed between the surfaces of the tensioned belt and the pulleys.

The term belt drive is usually reserved for drives using flat belts, while those using V-belts are referred to as V-belt drives. The latter are more commonly used in contractor's machinery.

Belt drives are employed for transmitting motion from one shaft to another when they are spaced at a distance equal to or greater than the sum of the pulley diameters. At closer spacing the belt is likely to slip excessively.

Belt drives perform well at high speeds. They absorb shocks and their design is simple. Their shortcomings are inability to transmit an exact rpm owing to belt slippage, necessity of taking up slack and complexity of maintenance.

Belt drives can be used to transmit motion between parallel shafts or between shafts at right angles to each other.

Pulleys are made of gray iron, and less frequently, of steel, or may be steel weldments.

Pulleys may be solid (Fig. 55*a*) or split (Fig. 55*b*); the latter are more convenient to install and remove from the

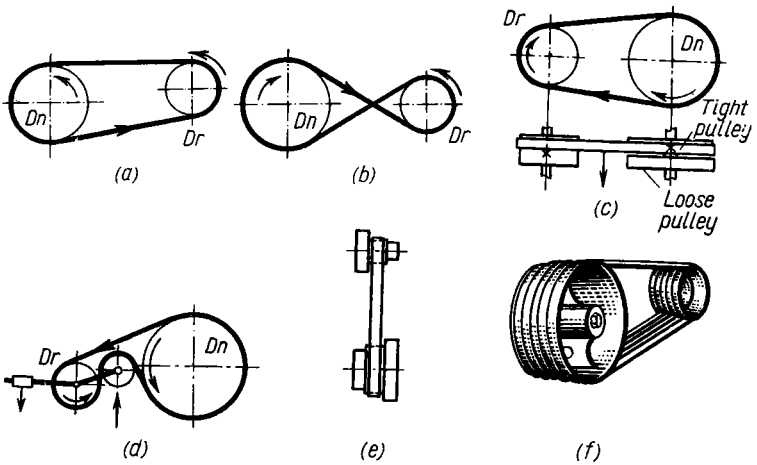


Fig. 54. Belt drives:
(*a*) open with flat belt, (*b*) ditto, crossed, (*c*) ditto, with loose pulley, (*d*) ditto, with swinging-arm idler, (*e*) ditto, with stepped pulleys, (*f*) V-belt drive

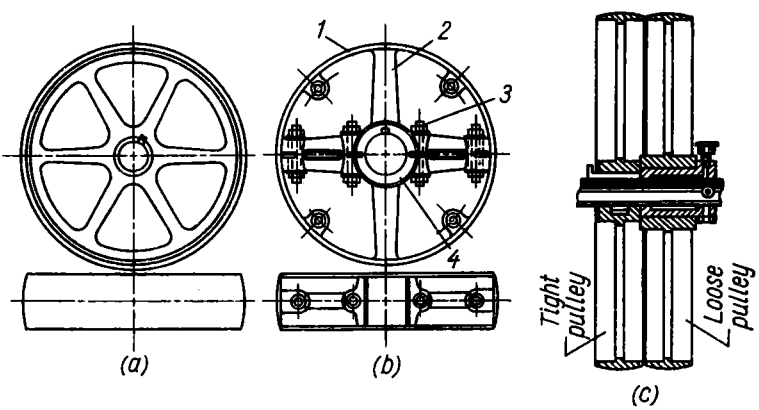


Fig. 55. Flat-belt drive pulleys:
(*a*) solid, (*b*) split, (*c*) loose and tight pulleys; *1*—rim, *2*—spoke, *3*—bolt, *4*—hub

shaft. A pulley consists of a rim *1*, spokes *2*, a hub *4*, and bolts *3*.

Rims of flat-belt pulleys are made slightly convex (crowned); in some cases they may be flat or tapered. The pulley rim should be 15 to 20 mm wider than the belt.

Pulleys for V-belts have trapezoid grooves in their rims.

Pulleys are made with spokes or with solid webs. The spokes of cast pulleys are of oval cross section, while those of welded pulleys are round. Pulleys with rims up to 300 mm wide are made with one row of spokes; if the rims are wider two rows of spokes are provided.

Tight pulleys have a keyway in their hub; loose pulleys are designed with a smooth hub. In the latter case the pulley has a bushing press-fitted into its hub, which is freely mounted on the shaft (Fig. 55*c*).

Belts are tensioned by increasing the distance between the shafts.

V-belt drives (see Fig. 54) have a number of advantages over flat belt drives. The most important of them are reduction of belt slippage, possibility of transmission at close between-shaft distances and less belt tension. The disadvantages of this type of drive are shorter belt service life, higher cost and complexity of maintenance.

V-belt drives can be used for transmitting rotation from one shaft to another parallel shaft when the distance between them is not less than the diameter of the larger pulley.

FRICTION DRIVES

Friction drives (Fig. 56) depend for their operation on the friction developed between rollers fixed on shafts and forced together.

These drives may be used between shafts with aligned axes (linked by a friction clutch), between parallel shafts and between crossed shafts.

With friction drives of special design the rpm and direction of rotation of the driven shaft can be varied. Rollers for such drives are made of steel or cast iron. To increase friction the working surfaces of such rollers are faced with rubberized fabric, pressed asbestos fibres or other materials.

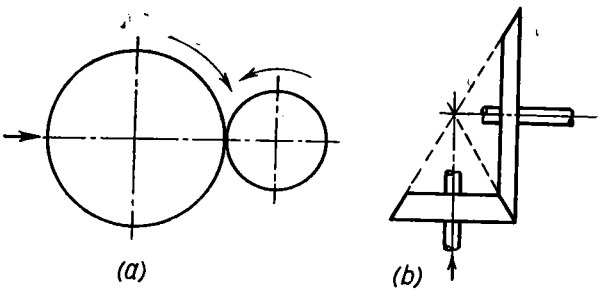


Fig. 56. Friction drives:
(*a*) between parallel shafts, (*b*) between intersecting shafts

The advantages of friction drives are their simplicity, convenience of maintenance and silent operation; their main disadvantage is inaccurate transmission of rpm.

20. Couplings and Clutches

Couplings and clutches serve for linking together shafts, linking shafts to pulleys, gears and other members and for connecting certain parts to each other. Special couplings and clutches are used to protect mechanisms against overload.

Depending on their purpose and nature of operation the following types of couplings and clutches are employed.

Shaft couplings which are used to join adjacent ends of shafts and cannot be disconnected (uncoupled) during operation of the machine.

Clutches which allow the shafts to be disconnected during operation of the machine, by hand or by means of a special device.

Self-acting clutches which disconnect the shafts automatically if the rpm or direction of rotation changes during operation.

Safety clutches which disconnect the shafts automatically if the transmitted load exceeds the permissible value.

Couplings are classed as follows according to the nature of the connection they make.

Solid couplings allow no relative rotation between the coupled shafts,

Flexible couplings allow slight relative rotation as a result of deformation (change in shape) of the intermediate components of the coupling, these components being made of elastic materials.

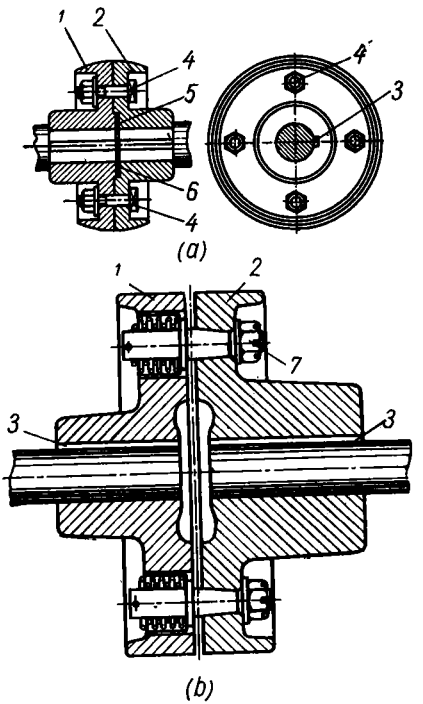


Fig. 57. Shaft couplings:
(*a*) flange coupling, (*b*) rubber bushing couplings; *1* and *2*—flanges, *3*—keys, *4*—bolts, *5*—recess, *6*—shoulder, *7*—nut

Friction couplings allow relative rotation between the coupled shafts by slippage of the mating surfaces if the load being transmitted becomes too high.

The flange coupling shown in Fig. 57*a* is a solid coupling. It consists of two flanges *1* and *2* keyed to the shafts by means of keys *3*. The flanges are bolted together with bolts *4*. For reliable alignment one of the flanges has a circular shoulder

6 which fits into a corresponding recess *5* in the other. Flange couplings can be used to couple shafts of different diameters, for which purpose the bores of the flange hubs are machined to the required size.

Flange couplings are used for shafts up to 400 mm in diameter.

Rubber bushing couplings (Fig. 57*b*) belong to the flexible type of couplings. They consist of two flanges *1* and *2* keyed to the ends of the coupled shafts with keys *3*. Studs are held rigidly in place in flange *2* with nuts *7*; these studs carry rubber bushings on their ends.

The ends of the studs with the bushings on them enter the corresponding holes in flange *1*.

Owing to the elasticity of the rubber bushings the coupling allows slight misalignment of the shafts, and reduces the effect of inaccurate assembly and shocks during operation.

Rubber bushing couplings are used for shafts up to 200 mm in diameter.

The claw clutch (Fig. 58*a*) consists of two halves *2* and *3*. Both halves have claws (or jaws) on their ends so arranged that the claws of one half fit into the spaces of the other. One of the halves *2* is mounted rigidly on shaft *1*, while the other half *3* slides along a feather key on the other shaft *5*.

The sliding half *3* has an annular groove (neck) *4*, on which the rubber yoke *6* (Fig. 58*b*) of the shifter is fitted. The shifter consists of two parts which are bolted together; the yoke trunnions fit into holes in the fork lever *7*.

The two halves of the clutch are engaged and disengaged by shifting the sliding half *3* by means of lever *7*. Thus, by means of the claw clutch, shafts *1* and *5* can be coupled or uncoupled. A similar mechanism is used for engaging and disengaging other types of clutches.

In friction clutches the load is transmitted by friction developed between the working surfaces of the clutch. The following types of friction clutches are used: disk-type, the working surfaces being the faces of two disks mounted on the ends of the coupled shafts; cone-type, with the conical surfaces of the members as the contacting friction surfaces, and radial clutches of the shoe and band types.

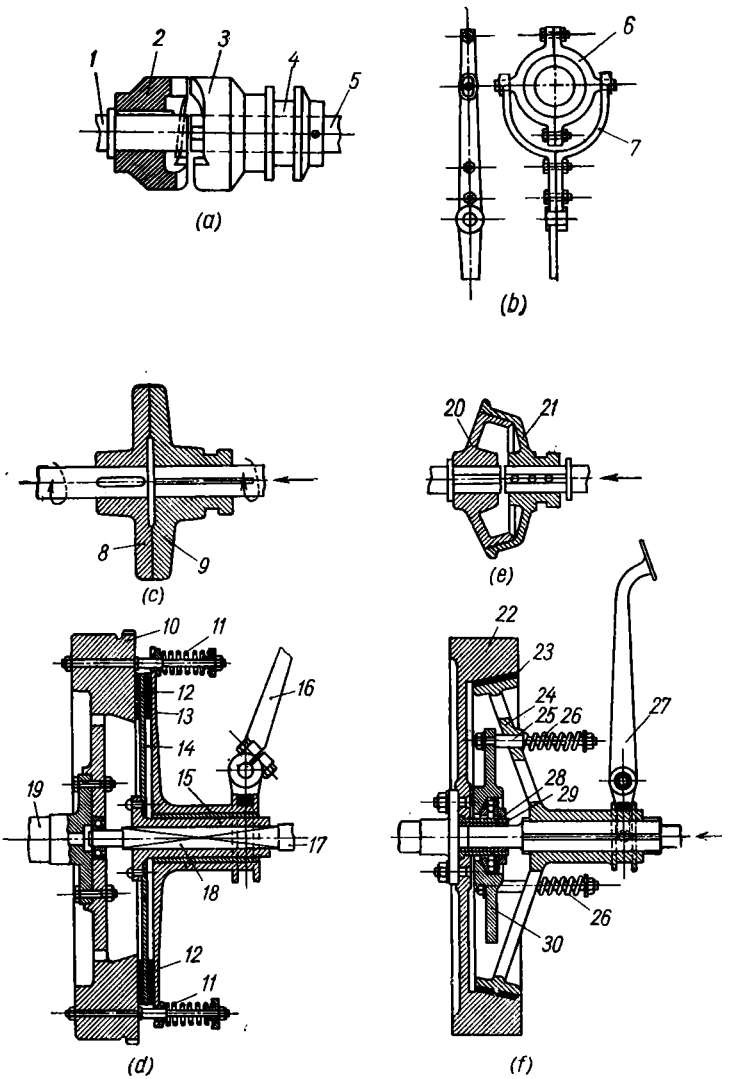


Fig. 58. Clutches:

(*a*) claw clutch, (*b*) engaging mechanism, (*c*), (*d*) schematic diagram and design of single-disk friction clutch, (*e*), (*f*) ditto, cone clutch; *1* and *5*—shafts, *2* and *3*—clutch halves, *4*—grooves, *6*—yoke, *7*—lever, *8* and *9*—disks, *10*—flywheel, *11*—springs, *12*—rings, *13*—pressure plate, *14*—disk, *15*—boss, *16*—lever, *17*—shaft end, *18* and *19*—shafts, *20*—male friction cone, *21*—female friction cone, *22*—female cone, *23*—ferodo lining, *24*—male cone, *25*—studs, *26*—springs, *27*—pedal, *28*—sleeve, *29*—bushing, *30*—disk

With respect to conditions of operation clutches fall into dry clutches, operating without lubricant, and oil clutches which operate in an abundance of lubricant.

Disk friction clutches may be of the single- or multidisk types.

Fig. 58*c* shows the principle of a single-disk clutch. Disk *8* of the clutch is keyed rigidly to the driving shaft, while disk *9* slides along a feather key on the driven shaft. The friction surfaces of the disks are faced with ferodo (asbestos fabric); disk *9* is shifted by means of a lever, screw or spring. When the disks are engaged the rotation of disk *8* is transmitted to disk *9* of the driven shaft due to the friction that arises between the two disks.

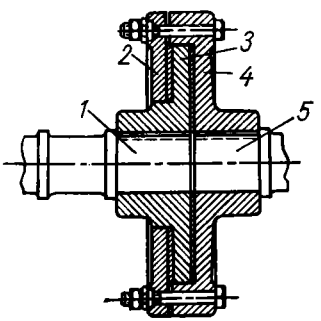


Fig. 59. Friction-type safety clutch:
1 and *5*—shafts, *2*—pressure plate, *3* and *4*—disks

Fig. 58*d* is one of the designs of single-disk friction clutches. Disk *14* of the clutch has ferodo rings *12* on its face which are compressed by springs *11* between the pressure plate *13* and the flywheel *10*. Disk *14* is riveted to a boss *15* seated on the square end *17* of shaft *18*, while flywheel *10* is fixed on the end of shaft *19*.

The shafts are connected by shifting the pressure plate *13* to the left along the sleeve, by means of lever *16*, and disconnected by shifting it to the right.

In multidisk friction clutches one group of disks is connected with the driving shaft, and another, with the driven one. The clutch is engaged by shifting the disks along one of the shafts and pressing them against the disks connected with the other shaft.

Cone friction clutches (Fig. 58*e*) have the following design: the male friction cone *20* is fixed rigidly on the end of the driving shaft, while the female cone *21* slides along a feather key on the end of the driven shaft. When cone *21* is shifted to the left the two cones engage and if the pressure between them is high enough friction will develop, owing to which

rotation can be transmitted from cone *20* through cone *21* to the driven shaft.

The cone friction clutch shown in Fig. 58*f* is of a slightly different design. Here, the male cone *24* is pressed by springs *26* against the female cone *22* which is seated on the driving shaft. The outer conical surface of component *24* is faced with ferodo *23*. The pressure is regulated by springs *26* on studs *25* fixed to disk *30* which is connected to the male cone *24*.

Sleeve *28* and bushing *29* ensure correct alignment of cones *24* and *22*. The cones are disengaged by means of pedal *27*.

Several types of safety clutches are manufactured. Fig. 59 shows a friction-type safety clutch with disks *3* and *4* fixed on shafts *1* and *5*, and pressure plate *2* which is pressed against disk *3* by tightening its bolt fastenings so that the clutch will transmit only a definite load; if the load exceeds the preset value, disk *3* will begin to slip between disk *4* and pressure plate *2* and the load will not be transmitted.

CHAPTER FOUR

ELEMENTS OF ELECTRICAL ENGINEERING

21. Fundamentals

STRUCTURE OF MATTER

All substances existing in nature may be divided into complex and simple substances. Complex substances can be decomposed into simple ones, for example, water can be decomposed into hydrogen and oxygen. Simple substances cannot be decomposed into other substances.

Simple substances are substances whose molecules consist of atoms of only one kind. Complex substances are substances whose molecules consist of different kinds of atoms.

The molecules of different substances contain different numbers of atoms. For instance, the water molecule contains one atom of oxygen and two of hydrogen, that of phosphorus pentoxide contains two atoms of phosphorus and five of oxygen.

The atom consists of a nucleus surrounded by very minute particles in continuous motion, called electrons. The nucleus carries a positive electric charge, and the electrons a negative one.

In the absence of external influences the atom is in electrical equilibrium, i.e., the positive charge on the nucleus is exactly neutralized by the negative charge of the electrons. The atom is thus electrically neutral.

Electric current is an ordered flow of electric charges. In metallic conductors electric current is due to the movement of electrons in a definite direction.

ELECTRIC CIRCUIT

Sources of electric energy connected by conductors to devices which consume the electric energy and are called loads comprise an *electric circuit* (Fig. 60). For an electric

current to flow through it, the circuit must be closed; if the circuit is disconnected (opened) the electric current will cease to flow. Besides the conductors, known as the wiring,

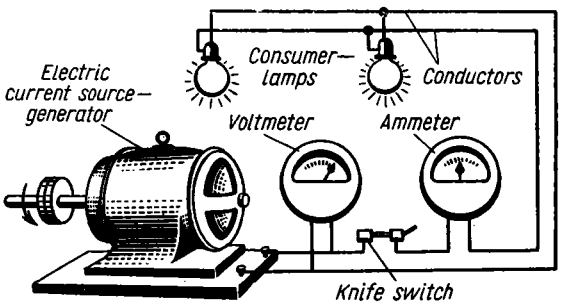


Fig. 60. **A simple electric circuit**

an electric circuit includes devices for switching the current on and off (switchgear), instruments for measuring electrical values (ammeters, voltmeters), and protective devices (fuses).

ELECTRIC CURRENT

To ensure a continuous flow of electric current in a circuit it is necessary to maintain a definite difference of electrical potential (*voltage*) across the poles of the source; this potential difference is thus the cause capable of producing the flow of electric current.

The unit of potential difference is the *volt* (V). Voltage, as it is more often called, is measured with a *voltmeter.* An idea of the magnitude of a volt can be had from the following: a galvanic cell sets up a voltage of about 1 V; a lead storage battery, of 2 V; the voltage in municipal and industrial networks may be 127, 220, 380 or 500 V; trams operate at a voltage of 550 V; electric traction, at voltages of 1,500 or 3,000 V; high-voltage overhead distribution lines have a voltage of 3,000, 6,000 or 10,000 V; high-voltage main power transmission lines operate at voltages as high as 110, 154, 220, 400 and 800 kV, and the voltage developed by lightning amounts to about 100 mill. V.

Current is the amount of electricity that flows through the cross section of a conductor per second, and is measured in *amperes* (A). Current is measured with an *ammeter*. The following examples will give an idea of an ampere: man can feel a current as low as 0.005 A passing through him; a current stronger than 0.05 A is dangerous, and one of 0.1 A is fatal to man; incandescent lamps draw currents from 0.25 to 1 A, and a tram, up to 100 A.

Voltage and current are the main electrical quantities characterizing an electric circuit.

Electrical resistance is the property of a conductor to hinder the passage of electric current through it. All the parts of an electric circuit offer resistance to the passage of electric current. The unit of electrical resistance is the ohm. This is the resistance offered by a conductor which will pass an electric current of 1 A when a voltage of 1 V is applied to its ends. The electrical resistance depends on the material of the conductor, its cross-sectional area and length, and also its temperature. The longer a conductor, the greater its resistance (the current has to flow a longer distance) and the larger its cross section, the lower the resistance (a conductor of larger cross section is less of an obstruction to the passage of current).

The best metals for electric wires are copper and aluminium. Aluminium wires have a higher resistance than copper ones of the same length and cross section, but they are lighter and cheaper.

Work and Power of Electric Current. Under the action of a force a body may move a certain distance: the force is then said to have done work.

Work done is the product of the force by the path traversed by the body under the action of the force. The magnitude of the force is measured in newtons, the path in metres and the work in joules (J).

The unit of work of electric current is the work done by a current of 1 A under a voltage of 1 V in the course of 1 second. This unit is called the watt-second (Ws) or joule (J). Thus, the work done by a current equals the voltage multiplied by the current and by the time, the voltage being expressed in volts, the current in amperes and the time in seconds.

The unit of work commonly used in industry is the kilowatt-hour (kWh) which equals 3,600,000 J.

Work done in one second is *power*. The unit of power is the watt (W) or the kilowatt (kW). The following will give an idea of a watt: electric lamps consume from 10 to 300 W; motors range in power from a few tens of watts to tens of thousands of kilowatts.

Energy is the capacity of a physical body to do work. Energy cannot be destroyed. It takes various forms and passes from one form to another. One of the forms of energy is called *electric energy*.

The electric energy needed for industrial purposes is produced by machines called *generators*.

The rotating part of a generator is called the *rotor*, and the stationary part, the *stator*. The field windings of the generator are fed with direct current from a special source. The alternating current produced is fed to the network through rings seated on the rotor. Generators are installed at power stations; they are driven by steam or water turbines or by internal combustion engines. Steam turbines operate on steam delivered to the turbine from steam boilers in which it is produced by heating water to a high temperature; the water is heated by burning a fuel (coal, peat, mazut, gas, wood) in the furnace of the boiler, or by utilizing atomic energy. Water turbines are actuated by water. Internal combustion engines consume liquid or gaseous fuel which is ignited in the engine cylinders.

Thus, generators are electrical machines which convert mechanical energy into electric energy. Therefore, to obtain electric power the corresponding amount of another kind of energy must be expended.

The performance of any machine is characterized by its efficiency.

Efficiency is the ratio of the useful work performed by a machine to the work input needed for actuating it. The useful work is always smaller than the work input, because part of the latter goes to overcome friction and to cover other losses.

For this reason, the efficiency is always less than unity.

Efficiency is a measure of the economics of a machine.

Electric power is transmitted from the generator along wires to the place of its consumption, where it may be converted into light by connecting an electric light bulb to the wires, into heat by connecting electric heating apparatus to them, or into mechanical energy by connecting the wires to electric motors. Electric motors actuate various machines connected to them through couplings, belt, chain, gear or other drives.

Conductors and Insulators. Not all bodies conduct electric current equally well. Metals are good conductors of electric current, and that is why the wires of an electric circuit are made of metal. Materials that conduct electricity are called *conductors.* With rise in temperature, the resistance of metallic conductors increases. in the case of copper wires, for instance, a temperature increase of 2.5°C raises the resistance by about one hundredth of their initial resistance.

Materials which do not conduct electric current are called *insulators.* Some insulators are: dry wood, porcelain, glass, rubber, resins, silk, mica, and air.

The current flowing through the conductors of an electric circuit must be insulated from surrounding articles. For this purpose the conductors are coated with a layer of insulation (Fig. 61), or porcelain or glass insulators (Fig. 62) are fixed to supports, and the conductors (wires) of the electric circuit are fastened to these insulators. The insulation on the surface of a conductor must be of high quality and of the adequate thickness. If the quality is low or the thickness insufficient, the insulation will be unable to withstand the circuit voltage and break down, following which a short-circuit current may appear between the wires at the point of breakdown (see p. 102).

If the wires are not insulated and are installed on nonconducting supports (porcelain or glass insulators), the distance between the wires, and from the wires to the wall or to the support to which the insulators are fixed, must be sufficient to ensure that the wires will not be short-circuited or faulted to earth.

Connection of Resistances. The external part of an electric circuit may consist of more than one consumer of electric energy or load. These loads may be connected in series, in parallel or in series-parallel.

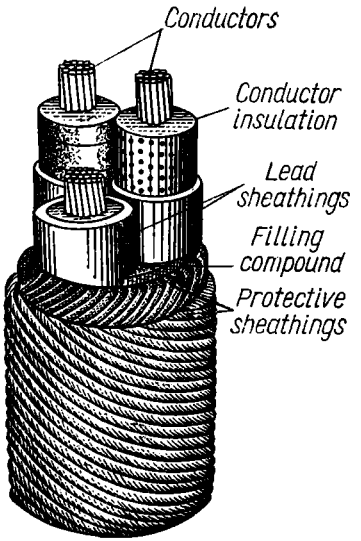


Fig. 61. Three-phase cable

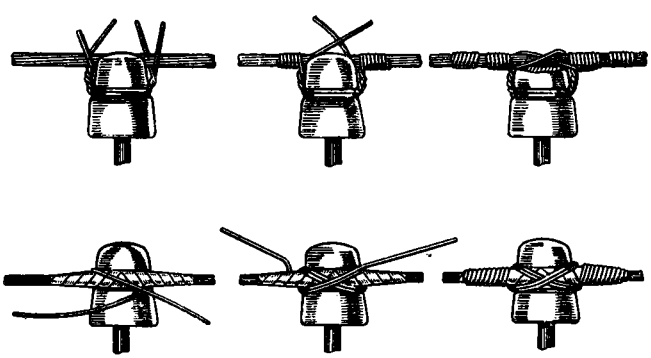


Fig. 62. Methods of fastening conductors to insulators

Several loads (electric lamps in this case) are connected *in series* when arranged as shown in Fig. 63*a*, one load following another. With such a connection, any change in resistance of one of the loads causes a change in the voltage across the others connected to it in series.

In *parallel connections* one of the terminals of all the loads is connected to one point of the electric circuit, and

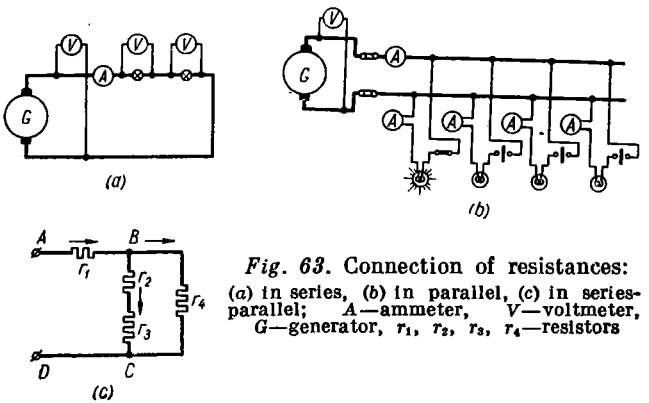


Fig. 63. Connection of resistances: (*a*) in series, (*b*) in parallel, (*c*) in series-parallel; *A*—ammeter, *V*—voltmeter, *G*—generator, r_1, r_2, r_3, r_4—resistors

the other terminal to another point (Fig. 63*b*). Thus, several loads are inserted between two given points of the electric circuit. All loads connected in parallel are under the same voltage.

Electric lamps and electric motors designed to operate at a definite voltage, must be connected in parallel.

In the *series-parallel connection* shown in Fig. 63*c*, two elements of the electric circuit *AB* and *BC* are connected in series, while the element *BC* consists of two parallel branches.

Thermal Action of Current. When an electric current flows through a conductor, the latter is heated because part of the electric energy is spent on overcoming the resistance of the conductor, i.e., in this case electric energy is converted into thermal energy.

The temperature of the wiring of a lighting circuit must rise only insignificantly, as otherwise a fire may occur. On the other hand, the element of an electric heater must become very hot.

The greater the current flowing through the wires, the greater they are heated: doubling the current increases the intensity of heating by four times. The longer the time the current flows through the wires, the more they are heated.

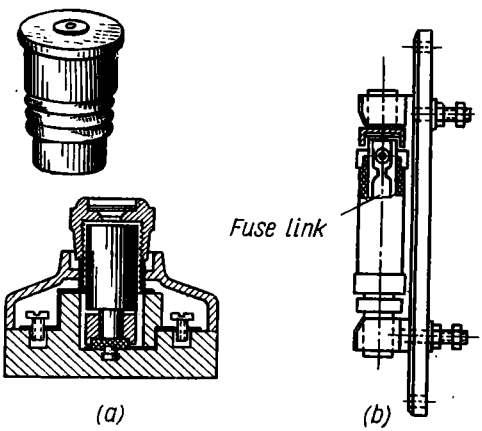


Fig. 64. Fuses:
(*a*) screw-plug fuse, (*b*) cartridge fuse

Thus, the amount of heat generated in a conductor is directly proportional to the square of the current, the resistance of the conductor and the length of time the current flows through the conductor.

If the cross-sectional area of a conductor is selected appropriately its temperature will rise insignificantly. The temperature of a conductor heated by current depends on how it is cooled. For example, to avoid overheating electric motors are fitted with fans.

The power rating of any electrical machine or apparatus depends in the long run on its temperature rise.

Short Circuit. Direct connection of the terminals of a source of electric power (generator) or of two wires in a network to each other, due to which only low resistance remains in circuit, results in a short circuit. Since the resistance in a short-circuited network is usually very much smaller than normal, the current in the conductor rises

sharply. The amount of heat liberated in the conductor during a short circuit can be so large that the insulation on the wires may catch fire, the wires may melt, i.e., the network and electrical equipment may be damaged. A short circuit may cause a fire.

The section in which a short circuit occurs must be quickly disconnected from the source, i.e., the circuit must be broken (opened). To open the circuit quickly in case of a short circuit, fuses are included in it.

Besides protecting the equipment from short circuits, fuses protect the wires from overloads during which the electric current rises above the value permissible for their cross section.

A fuse (Fig. 64) serves as a short section of an electric circuit and is made with a link of thin wire or strip which will melt if the current increases excessively. Fuses are installed on the outgoing side of the supply switch to enable the electrician to replace blown fuses with the circuit fully disconnected from the main.

Screw-plug fuses (Fig. 64*a*) are used for currents up to 60 A, cartridge-type (Fig. 64*b*), for currents up to 400 A.

Besides fuses, other more complicated devices are used, which switch off a unit automatically.

MAGNETISM

Magnetism is the property of certain kinds of iron ores and magnets to attract steel objects. A *magnetic field* is the space throughout which the forces of magnetic attraction can be detected.

A magnetic (compass) needle will turn in a magnetic field until it points in the direction of a line running from pole to pole of the magnet. The direction in which the needle points when placed in a magnetic field is called the *direction of the magnetic field* at that point, and is indicated by the north pole of the needle. The direction of a magnetic field is denoted by lines called the lines of force of the magnetic field, or lines of magnetic force.

A magnetic field is uniform if its lines of force are spaced equally. Such a field will be set up between the unlike poles of two magnets or between the two poles of a horseshoe

magnet. Lines of magnetic force are directed from the north pole of a magnet to its south pole.

The north pole of a magnet is that which repells the end of a magnetic needle which points to the north.

Hence, like poles repell, and unlike poles attract each other.

Electromagnetism. An electric current flowing through a conductor gives rise to a magnetic field around it. The

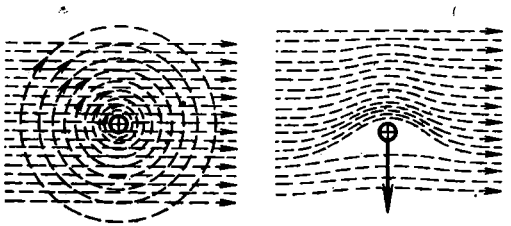


Fig. 65. Current-carrying conductor in the field of a permanent magnet: *a*) separate action of magnetic fields, (*b*) combined action of magnetic fields

lines of magnetic force around a straight conductor form concentric circles with the conductor at their centre (Fig. 65).

The position a compass needle will take in the field around a conductor, and, therefore, the direction of the magnetic field, depend on the direction of the current in the conductor.

Two parallel conductors with current flowing through them in the same direction will be attracted to each other; if the current is flowing in opposite directions, parallel conductors will repell each other.

If a conductor is wound into a helical coil (Fig. 66) and current is passed through this coil (solenoid), a magnetic field will be set up around each of the turns. Similar to the poles of a magnet, the resultant magnetic field will form, in effect, a north and a south pole at the ends of the coil. Looking at the end of the coil, the direction of the current may be clockwise or counterclockwise. The end at which the current is seen to flow clockwise is where the south pole will be, and that at which it is seen to flow counterclockwise is the north pole.

Since a solenoid possesses the properties of a magnet, a steel rod will be drawn inside the coil. The magnetic properties of a solenoid are augmented if the number of turns and/or the current flowing through the coil are increased. Inserting a steel rod (core) into the solenoid increases the magnetic properties of the latter.

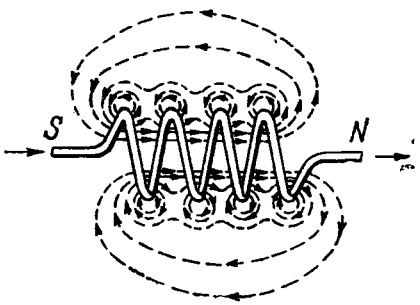


Fig. 66. Magnetic field of a helical coil

Thus, when an electric current flows through insulated wire wound round a steel core the latter acquires magnetic properties and becomes an electromagnet.

The magnetic field set up around conductors through which current is flowing has the same properties as the field of a permanent magnet.

Electromagnets are used in various devices ranging from electric bells, electromagnetic brakes, air circuit breakers and contactors for electric motor control to complex signalling and automatic control devices and systems.

Large-size electromagnets are used on cranes to attract objects of iron and steel and thereby serve to hoist and handle them.

Interaction Between a Current-Carrying Conductor and a Magnetic Field. If we place a conductor through which a current is flowing in a magnetic field, an interaction will be observed between the conductor and the magnetic field. The greater the current passing through the conductor, the larger the force of interaction.

The magnetic field makes the current-carrying conductor move at right angles to the lines of magnetic force.

In the conductor shown in Fig. 65 the current is flowing away from the observer (indicated by the cross). In this case the magnetic field about the conductor will have a clockwise direction. Suppose the magnetic field set up by the magnet is directed from left to right.

It is evident from the figure that the field of the magnet and that of the conductor have the same direction above the latter, and opposite directions below it (see Fig. 65*a*). Therefore, the lines of magnetic force will be spaced more densely above the conductor and less densely below it, so that the lines are bent (see Fig. 65*b*). Owing to the tendency of the lines to straighten themselves, the conductor will be moved downwards. If we reverse the direction of the current or that of the magnetic field, the conductor will be moved upwards. This principle is the basis of electric motor action.

Magnetic Induction and Magnetic Flux. The force with which a magnetic field acts on a conductor carrying electric current depends on the intensity of the current, on the length of the conductor and on the properties of the magnetic field. The greater the current passing through the conductor, the larger this force; if there is no current flowing, there will be no force.

The force with which a magnetic field acts on a conductor is directly proportional to the length of the latter. If the length of the conductor is doubled, the force acting on it will be twice as large.

The magnitude and direction of the force acting on a conductor of constant shape through which a current of constant intensity is passing, will vary from point to point as the conductor moves through a magnetic field.

The properties of a magnetic field at its different points are characterized by the magnetic induction. If we imagine the magnetic field as consisting of lines of magnetic force we can judge as to the magnitude of the magnetic induction by the density of the lines of force of the field (flux density). Where the lines increase in density they indicate an increase in magnetic induction which may be expressed as the number of lines passing through one square centimetre of a surface perpendicular to the lines of magnetic force. The total number of lines of force piercing a small given surface at

right angles equals the magnetic induction multiplied by the area of the surface. This product is called the *magnetic flux.*

Electromagnetic Induction. If a conductor moves through a magnetic field (Fig. 67) so as to intersect the lines of

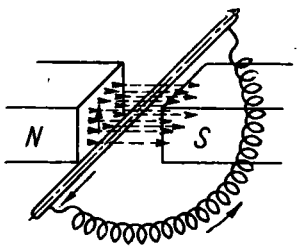


Fig. 67. Induction of an electromotive force in a conductor

magnetic force, an electromotive force will appear (be induced) in the conductor. This phenomenon is known as *electromagnetic induction.*

The electromotive force developed in the conductor and the current it causes to flow are called *induced* electromotive force and current.

DIRECT AND ALTERNATING CURRENT

A *direct current* is one that passes through a conductor in one direction without changing its magnitude.

A current which changes its direction and magnitude periodically is called *alternating current.*

Rectilinear motion of a conductor in a magnetic field is inconvenient to accomplish, and so rotary motion is generally used to develop electromotive forces, the conductor being made essentially in the form of a revolving coil *3* (Fig. 68) fixed on an insulated shaft *7*. The ends of the coil are connected to two insulated rings *4*, with which the strips (brushes) *5* are maintained in contact. These strips serve as sliding contacts with the surfaces of the rings as the rings rotate. The contacts are connected by wires *6* to a voltmeter *1*, and the coil is arranged in the field of an electromagnet *2*.

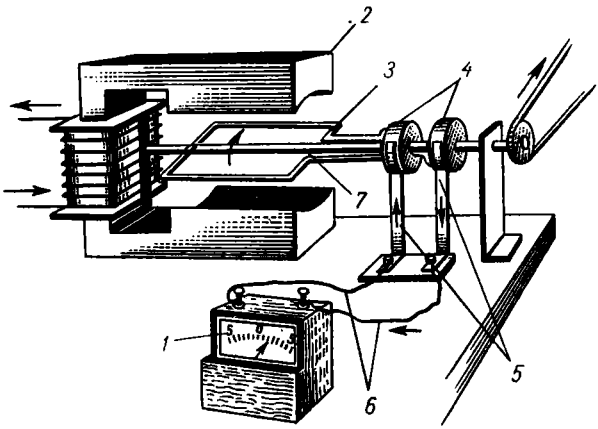


Fig. 68. Key diagram of a device for producing alternating current: *1*—voltmeter, *2*—electromagnet, *3*—coil, *4*—slip rings, *5*—brushes, *6*—wires, *7*—shaft

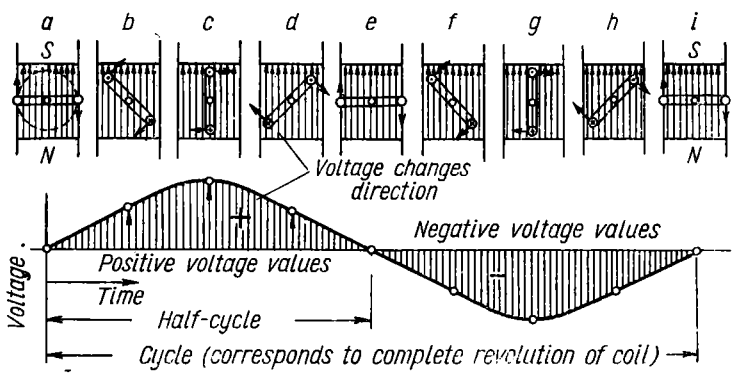


Fig. 69. Variation of voltage on the terminals of a rotating coil

The rotation of the coil in the magnetic field causes the magnetic flux linking it to increase and decrease continuously first in one direction and then in the other. This is how an alternating current is produced.

When the coil is in position *c* (Fig. 69), no magnetic flux links with the coil: not a single line of magnetic force can pierce the coil (turn) because its plane is parallel to the lines of the field; in position *a* the amount of magnetic flux linking the coil equals the product of the magnetic induction by the area of the coil, since the coil plane is normal to the lines of magnetic force.

The magnitude of the voltage induced in the coil will hence not be the same at different positions of the coil and the current passing into the circuit will therefore also vary.

In position *a* the voltage in the coil is zero. As the coil rotates and the angle of rotation increases, more and more lines of magnetic flux go out of linkage with the coil, and the rate at which this happens rises continuously. This therefore results in a rise in the induced voltage generated due to the change in the magnetic flux piercing the coil.

In position *b* the current is flowing toward the observer in the upper part of the coil, and away from him in the lower part.

In position *c* the voltage reaches its highest value because here the coil is moving at right angles to the lines of magnetic force and a slight movement of the coil is enough for it to be pierced by the greatest number of lines in a given interval of time.

In position *d* the direction of the current is the same as before, but its magnitude is smaller.

In position *e* the direction of motion coincides with the direction of the lines of flux, and since the number of lines linked with the coil does not change the voltage drops to zero.

After the coil has passed through the first half of one revolution, the voltage and current in it reverse their direction. The subsequent positions *f*, *g*, *h*, *i* correspond to positions *d*, *c*, *b*, and *a*, respectively; the only difference is that in these new positions the direction of the current is opposite to what it was during the first half of the revolution.

When the positions of the coil alternate as described, the current is produced within, and passes through, a single circuit, and is called single-phase alternating current.

The time during which the current goes through a full change in the course of one revolution of the conductor (coil) in the magnetic field is called a *cycle*. The number of cycles per second is called the *frequency* (in the U.S.S.R. the standard frequency for alternating current is 50 c/s).

The kind of current most generally used in practice is three-phase alternating current. The following will give an idea of three-phase current. Suppose we have three a-c generators which produce alternating single-phase currents of the same voltage and frequency so that each current is being generated one third of a cycle later than the current preceding it. The voltages therefore do not reach their maximum and zero values simultaneously in the three generators and are said to differ in phase.

Current can flow only through a closed circuit, and if we connect one terminal of each of the three generators at a common point (Fig. 70*a*) no current will flow in any of the generator windings. Such a connection is called a *star* (or Y) *connection*.

With this connection four terminals are formed, namely, *0*, *1*, *2*, and *3*, and there will be a voltage across any pair of terminals or wires connected to the terminals.

The wire connected to the terminal common to all three generators is called the *neutral conductor*. The voltages between the neutral conductor and each of the line conductors are identical in value and equal the voltage of each separate generator. These voltages are known as *phase voltages*.

The voltage between the phases *1-2*, *2-3*, and *3-1* will be different, as in this kind of connection the voltage is a combination of two generator voltages connected in series. These voltages are called *line voltages*.

One of the terminals of each generator is conventionally called the "beginning", and the other, the "end" of the winding, it being considered that the voltage is positive when it is directed from the "end" of the winding to its "beginning". When these generators are star-connected, the three terminals connected to the common point must be all "beginnings" or all "ends".

For the three line voltages to be equal, the phase difference between any two of the generator voltages must equal 1/3 of the alternating-current cycle. For instance, the voltage of phase *1* leads that of phase *2* by 1/3 cycle and lags

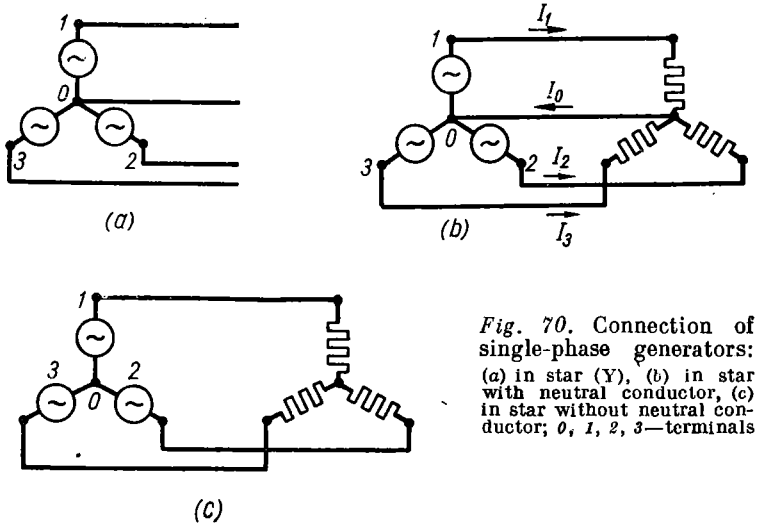


Fig. 70. Connection of single-phase generators: (*a*) in star (Y), (*b*) in star with neutral conductor, (*c*) in star without neutral conductor; *0*, *1*, *2*, *3*—terminals

that of phase *3* by 1/3 cycle; the voltage of phase *2* lags that of phase *1* by 1/3 cycle and leads that of phase *3* by 1/3 cycle.

If equal resistances are connected between wires *1* and *0*, *2* and *0*, and *3* and *0* (Fig. 70*b*) the currents I_1, I_2, and I_3 passing through each of these resistances will be equal in value but different in phase. The sum of these three currents I_0 will pass through the central neutral conductor, but as the currents and phase voltages differ in phase from one another by 1/3 cycle their vector sum will be zero; hence, there will be no current in the neutral conductor.

Therefore, if the phases are equally loaded, the neutral conductor becomes unnecessary and the current can be transmitted through three line conductors as shown in Fig. 70*c*. In this case the current flows from the generators to the load through one or two wires and back through two or one, respectively, passing from the generator alternately through the

first wire, then the second, etc., and returning through each of them in turn.

Usually, the current is transmitted over three conductors, the fourth, connected to the common or neutral point,

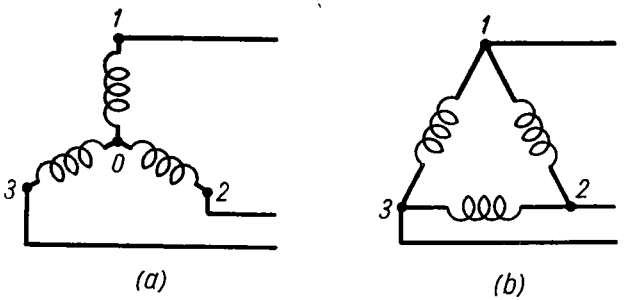


Fig. 71. Diagram of three-phase generator with coils connected: (*a*) in star, (*b*) in delta (mesh); *0*, *1*, *2*, *3*—terminals

being used when the loads on the three phases are not equal (unbalanced).

In reality, the three-phase voltages are obtained from a single three-phase generator rather than from three of them, this generator having three independent windings, each of which serves as a separate generator.

A diagram of a three-phase generator with a star-connected winding is shown in Fig. 71*a*.

Another kind of connection that is often used is the *delta* or *mesh connection* (Fig. 71*b*). In this connection the end of each phase winding is connected to the beginning of another.

In the absence of any load, there will be no current in the generator winding because the vector sum of all three-phase voltages equals zero at each instant: two of the phase windings tend to send current in one direction while the third counteracts them, the part played by each phase winding alternating all the time.

In a delta-connected generator the voltage across the conductors connecting it with the load, i.e., the line voltage, is equal to the voltage of the corresponding phase winding of the generator.

It is evident from the diagram that the line voltage is at the same time the phase voltage.

Fig. 72 is a diagram of one phase of a three-phase generator. In this generator the three coils of each phase are arranged round the revolving poles of the electromagnets

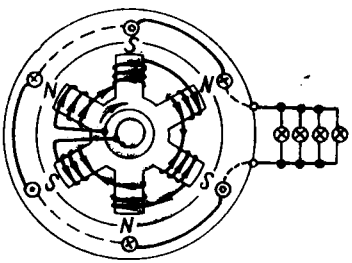


Fig. 72. Diagram of one phase of a three-phase alternating-current generator

on the rotor which are energized by an auxiliary d-c generator (exciter). These stator coils are spaced so that they are 120 electrical degrees apart, and the beginnings of the phase windings are connected together in a common point, while their ends are brought out for connection to the line conductors.

The three single-phase a-c circuits of a three-phase generator produce voltages which are equal in value but differ in phase by one third of a period.

Three-phase alternating current is the most widespread in practice because the transmission of electricity as three-phase current requires 25 per cent less metal, and three-phase generators and motors are simpler and cheaper than single-phase units.

TRANSFORMERS

A very important factor in transmitting electric power over considerable distances is proper selection of the voltage and current. The cross-sectional area which the line conductors must have depends on the current to be passed through them: the higher the current, the larger the cross-section-

al area of the wires required. Therefore, when transmitting electric power, the current should be lowered to a value as small as possible. This can be achieved by raising the voltage, since electric power is proportional to the product of the voltage by the current.

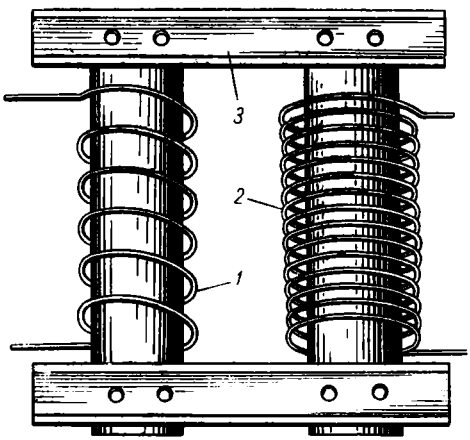


Fig. 73. Diagram of transformer:
1, 2—windings, *3*—core

The greater the power and the longer the distance over which it is transmitted, the higher must be the voltage. That is why transmission lines for supplying power to areas a long distance away from a district power station use high voltages. At the area where the power is to be consumed, the transmitted voltage is stepped down to 6,000 or 10,000 V and then to 380 or 220 V at the site of consumption.

Apparatuses for converting alternating current of one voltage into alternating current of another voltage are called *transformers.*

Transformers which raise the voltage are called *step-up transformers*, and those which lower the voltage are called *step-down transformers.*

Fig. 73 is a diagram of a transformer. Two windings of insulated wire having a different number of turns are arranged on a closed steel core. The high-voltage winding has

the larger number of turns, and the low-voltage winding, the smaller number. The alternating current passing through the primary winding *1* sets up a magnetic flux in the core. This magnetic flux then links with the turns of the secondary winding *2*, to which the loads are connected. Since the flux alternates, a voltage is induced in the secondary winding, the magnitude of which is proportional to the number of turns in the winding.

In the case under consideration, the transformer acts as a *step-up* transformer, while if the ratio of turns were the inverse, or the connection of the source and the load to the transformer were reversed, it would work as a *step-down* transformer.

The core *3* and the winding comprise an assembly which is generally placed in a steel tank filled with mineral oil and fitted with a tight cover. The oil serves for better cooling of the winding and also as an insulating medium. To protect the winding and oil from moisture, the tank is made so that air will not get into it.

Recently dry-type transformers have found application along with oil-immersed transformers. Such are the transformers used in the КТП unit-type transformer substations.

22. Polyphase Induction Motor

The most commonly used motor in industry is the polyphase induction motor.

The polyphase induction motor is based on the interaction between a revolving three-phase magnetic field and the currents induced by this field in a system of conductors arranged to rotate with a rotor mounted on a shaft.

The stator of a polyphase induction motor (Fig. 74) consists of a frame and stator core with a three-phase winding arranged in the slots on the inside of the core to form three symmetrically arranged phase windings. All three phase windings of the three-phase system of a polyphase induction motor are identical. Owing to this, under normal operating conditions, such a motor represents a balanced load for a three-phase supply system.

The currents in the phase windings differ in phase by 120 electrical degrees.

The stator winding of the induction motor serves to produce the rotating magnetic field. The rotor placed within the stator of the induction motor is a cylinder built up of electrical steel stampings (laminations) which are insulated from one another to avoid eddy current losses.

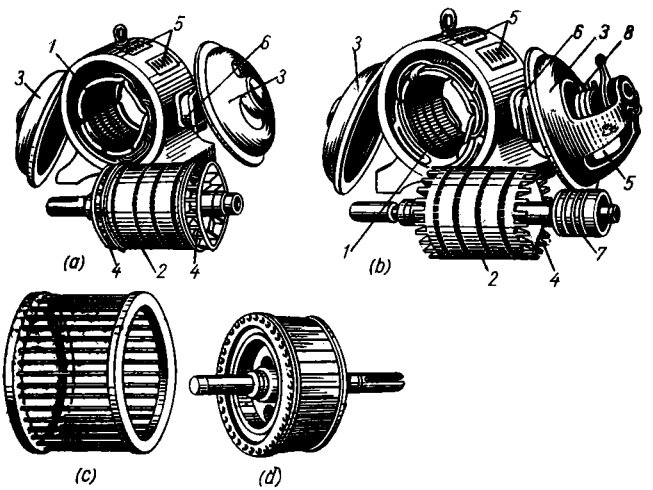


Fig. 74. Polyphase induction motors, dismantled:
(*a*) squirrel-cage type, (*b*) slip-ring type, (*c*) squirrel cage, (*d*) squirrel-cage rotor; *1*—stator, *2*—rotor, *3*—endshields, *4*—fan, *5*—ventilation slots, *6*—terminal box, *7*—slip rings, *8*—brush-holders and brushes

The rotor windings are arranged in the slots provided in the built-up steel cylinder. In low-powered motors (1.5 or 2 hp) the winding is made in the form of a "squirrel cage" consisting of a number of thick copper bars with their ends brazed into common end rings, or of a cast-in squirrel cage of aluminium, wherefrom the name squirrel-cage induction motor.

In more powerful motors, where large starting currents arise and might endanger the unit, a starting rheostat (see Sec. 23) is connected in series with the rotor winding. Such motors have a brush-lifting device which makes it possible to connect the starting rheostat in series with the rotor winding by lowering the brushes and then switch it out by raising them. These motors are known as wound-rotor

or slip-ring induction motors. When the brushes in such motors are lifted, another device short-circuits the rotor winding at the slip rings.

A wound rotor is furnished with three slip rings and has three insulated phase windings which are star-connected and have their three remaining leads brought out and connected to the three slip rings seated on the rotor shaft. The slip rings are insulated from one another and from the rotor shaft. When the motor is assembled, it is fitted with a set of brushes which are connected to the motor starting rheostat and can be lowered onto the rings for starting and then lifted after a start.

In an induction motor, as a result of the interaction between the revolving magnetic field produced by the stator winding and the current induced in the rotor winding, the rotor begins to run in the same direction as the magnetic field, i.e., the magnetic field acts as if it drags the rotor after it.

With increasing load the speed of an induction motor decreases but slightly (2-5 per cent) and this makes it possible to employ induction motors extensively in industry and in civil engineering.

The stators of both types of induction motors are of the same design; they consist of a frame, a stator core, and the stator winding.

The stator frame is an iron or aluminium casting which serves simultaneously as the motor enclosure, and to which the endshields which house the bearings are bolted. The stator core consists of one or several stacks of steel laminations insulated from each other, compressed and secured to the inside of the stator frame. Each stator core has slots in which the coils of the three-phase windings are inserted. The leads of the phase windings are brought out to a terminal box on the side of the motor frame.

Induction motors are generally designed so that they can operate at either of the two voltages 127/220 or 220/380. This is indicated on the nameplate fixed to the cylindrical part of the frame. This is possible because the stator phase windings can be connected in two ways.

The phase windings of the stator can be either star- or delta-connected (Fig. 75). If the voltage in the circuit to which the motor is connected is the higher one indicated

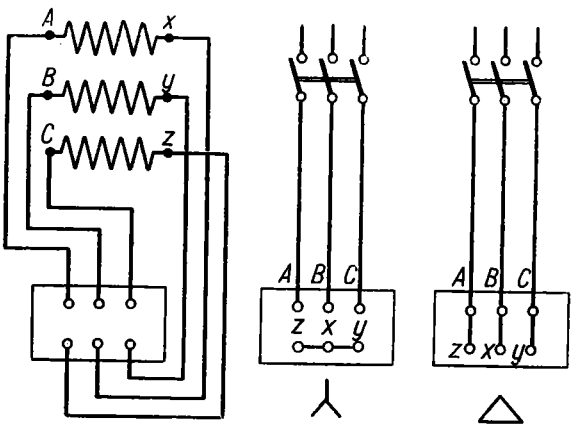


Fig. 75. Arrangement of stator winding terminals in terminal box and their connection in star and in delta

on the nameplate, the windings should be star-connected; if it is the lower one, they should be delta-connected.

Before connecting any motor to the supply, check to see that the stator connection conforms to the voltage rating indicated on the nameplate and to the supply voltage.

The rotor shaft runs in oil-ring sleeve bearings, or ball or roller bearings. The bearings are fixed in the end shields.

A driving pulley, a pinion, or a coupling is seated on one end of the rotor shaft for transmitting the rotary motion to the shaft of a machine operated by means of a belt or gear drive or by direct connection (with a coupling).

Squirrel-cage motors are of more rugged design and smaller in size than slip-ring motors; they are easier to control and maintain and that is why these motors have found such wide application.

In operation, electric motors generate heat which raises the temperature of their windings. If the temperature rises too high, the winding insulation may burn out, putting the motor out of commission.

To cool the winding constantly, a fan is fixed on the rotor shaft to blow air through the motor; this air cools the windings and stator and rotor cores, and is exhausted through special openings.

23. Electric Motor Switchgear

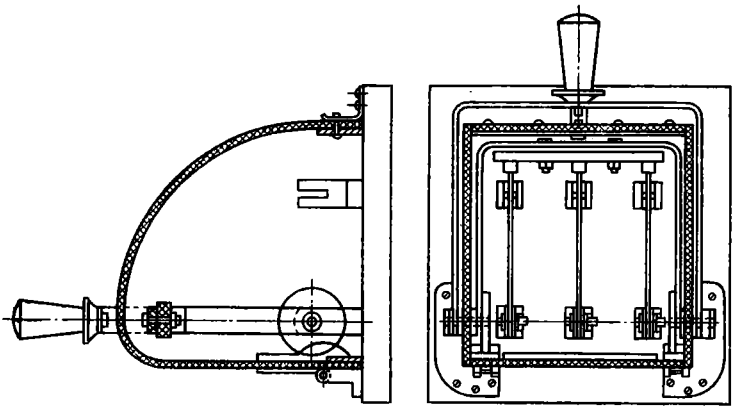
Induction motors are controlled by knife switches, starting rheostats, oil switches, magnetic starters, magnetic contactors, controllers operated in conjunction with resistor boxes.

Knife switches (Fig. 76*a*) serve for opening and closing low-power and low-voltage circuits. Their live parts must be housed under safety covers. Switches of this class, together with a set of fuses, an ammeter and a voltmeter, are available as units arranged in special metal-clad power distribution boxes. Such a box (Fig. 76*b*) consists of a cast-iron casing *1* and a door *2*. Inside the box is mounted a knife switch, the fuses and an ammeter. The switch operating lever *3* is on the outside. The door is mechanically interlocked with the handle to make access to the inside of the box possible only when the switch handle is in the "Off" position.

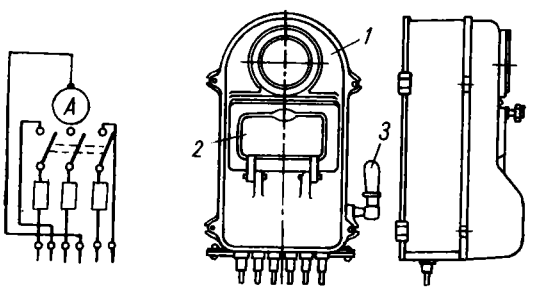
Magnetic contactors are actuated by electromagnets which can be remotely controlled. By means of a contactor large currents can be switched on and off at frequent intervals with hardly any physical effort, as all that has to be done is to press a push button to energize or de-energize the coil of the electromagnet which operates the contactor.

Essentially a magnetic contactor (Fig. 77) is of the following design: a coil *1* is placed on a stationary magnetic core *2* which can attract a magnetic armature *3* fastened to a pivoted arm with a contact *5* bolted to its top. This contact makes with the contact *4* when the coil is energized and magnetizes the stationary core. As soon as the coil is de-energized, the movable armature falls back or is returned by a spring into the position shown in Fig. 77*a* (main contacts open). This magnetic contactor is of the normally-open type; there are also normally-closed magnetic contactors whose main contacts are maintained closed when the coil remains de-energized.

A *magnetic starter* comprises an enclosure of pressed steel or other material containing a three-pole normally-open magnetic contactor. The contactor incorporates auxiliary contacts and a thermal overload relay in two of the poles.

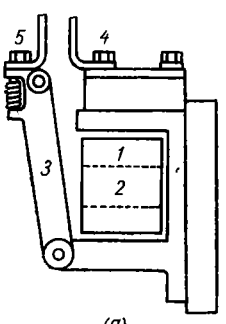


(a)

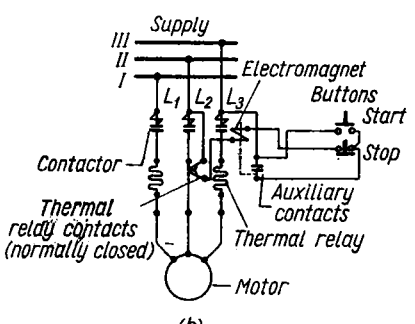


(b)

Fig. 76. Knife switch and distribution box:
(*a*) three-pole knife switch, (*b*) distribution box: *1*—casing, *2*—door, *3*—lever



(a)



(b)

Fig. 77. Schematic representations of switch gear:
(*a*) contactor, (*b*) nonreversing magnetic starter; *1*—coil, *2*—core, *3*—armature, *4*, *5*—contacts

Magnetic starters are supplied with a separate or built-in push button station with "Start" and "Stop" buttons.

The diagram in Fig. 77*b* illustrates the operation of a magnetic starter. Depression of the "Start" button makes the following circuit: conductor L_2—normally-closed thermal overload relay contact—electromagnet coil—"Stop" push button contact—"Start" push button contact—conductor L_3. The resultant flow of current through the coil causes the armature of the electromagnet to be attracted to the core, turn the insulated shaft of the contactor, and close the three pairs of main contacts. The motor is thus connected to the supply.

When the shaft of the contactor turns, it also closes the auxiliary contacts to shunt the current energizing the electromagnet coil round the "Start" push button contact. Now the "Start" button may be released. The coil current will then flow from conductor L_2 through the electromagnet coil, the normally-closed "Stop" push button contact, the lower conductor, and the normally-closed auxiliary contacts to conductor L_3.

The magnetic starter is switched off whenever the "Stop" button is depressed to break the electromagnet coil circuit, when the thermal relay trips owing to an overload of more than 15 per cent opening its contact, or if the supply voltage disappears or drops to 50-70 per cent of its rated value.

The magnetic starter described above protects a motor from overload and enables it to be started remotely, but in only one direction of rotation. There are also reversible starters which make it possible to reverse the direction of rotation of the motor whenever this must be done frequently. If a motor when first connected to a magnetic starter runs in the wrong direction, its direction of rotation can be reversed by just interchanging any two of the motor phase connections.

Starting and Field Rheostats. The first are devices used for starting, the second, devices for controlling the speed of slip-ring induction motors. Starting rheostats are designed to withstand heating only during the short starting period and are therefore unsuitable for controlling motor speed. Speed control rheostats are designed for continuous operation and are used for starting and for speed control.

The most common types are metallic rheostats consisting of metal resistor elements, switches, switching contacts to provide several steps of resistance, connection wires, terminals, and a number of minor parts, all housed in a common enclosure to form a compact unit.

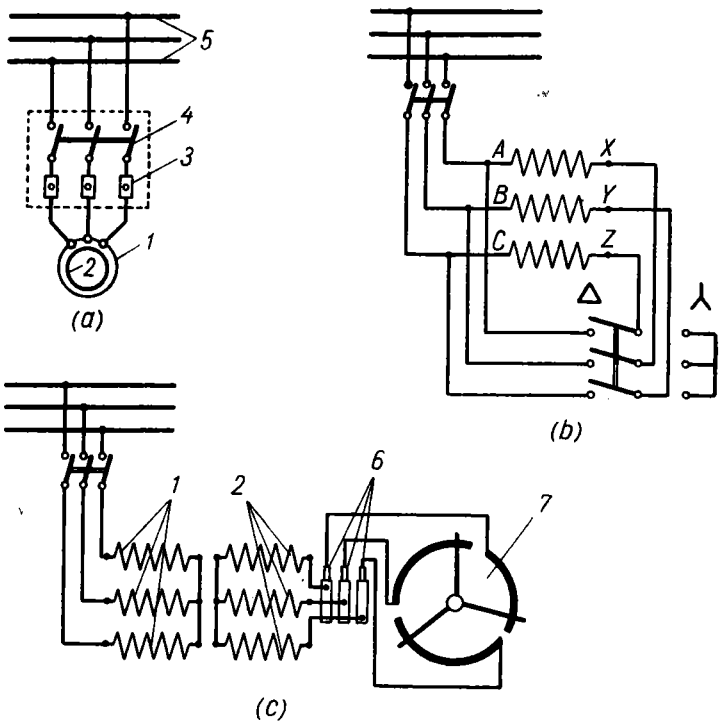


Fig. 78. Starting diagrams for electric motor:
(*a*) squirrel-cage motor with knife switch, (*b*) ditto, with switching from star to delta, (*c*) slip-ring motor; *1*—stator winding, *2*—rotor winding, *3*—fuses, *4*—knife switch, *5*—supply, *6*—brushes and slip rings, *7*—starting rheostat

The resistor elements of rheostats are made of wires or ribbons of high-resistance alloys such as nichrome, fechral (an iron-base alloy containing chromium and aluminium), nickeline (a nickel alloy) and others.

Rheostats are most frequently air-cooled or oil-filled.

Air-cooled rheostats get hot quickly, but cool down just as quickly. Air cooling is used for both starting and field rheostats.

Oil-filled rheostats are metallic resistors immersed in oil contained in a steel tank. As they take a relatively long time to cool down, oil-filled rheostats can be employed only for starting.

Low-powered (up to 10 kW) squirrel-cage induction motors are started by directly connecting them to supply by closing the switch or starter, and are stopped by directly switching off the supply (Fig. 78*a*). A motor starting circuit that is often used involves switching the phases of the motor over from star- to delta-connection as soon as the motor gains speed (Fig. 78*b*). This reduces the starting current three-fold. Besides the above method, various types of oil-filled starters and magnetic starters are used to start motors of this type and power rating.

Slip-ring induction motors are started with the aid of rheostats connected to the rotor circuit.

The starting diagram for a slip-ring induction motor with a starting rheostat is shown in Fig. 78*c*. Before starting, the rheostat handwheel is rotated clockwise to set the contact arms on the first resistor switching contacts. This introduces the entire resistance of the rheostat into the rotor circuit. Then the switch connecting the stator winding to the supply is thrown in. As the motor gains speed, the rheostat handwheel is gradually rotated counterclockwise. The resistor elements are thereby cut out of the circuit one by one and the speed of the motor increases. As soon as the sliding contact arms pass on to the last stationary switching contacts all the resistance of the rheostat is completely cut out of the circuit and the motor runs at its rated speed. The motor is stopped by simply opening the supply switch.

CHAPTER FIVE

DESIGN AND OPERATION OF MACHINES AND EQUIPMENT FOR PRODUCING AND PREPARING CRUSHED STONE, GRAVEL AND SAND

The volume of work involving the use of concrete and reinforced concrete in modern civil engineering keeps growing constantly and rapidly; this gives great impetus to the rock industry quarrying concrete aggregates: crushed stone, gravel and sand.

In the construction of buildings and structures use is made nowadays of prefabricated parts of reinforced concrete and other materials, which are manufactured at special plants. The extensive application of prefabricated reinforced concrete parts creates a growing demand for high-quality aggregates, especially finely crushed stone (3-10 mm and 3-20 mm sizes). The increasing use of reinforced concrete for piping, high tension line supports and other responsible parts makes it necessary to employ washed sands of specified grain sizes.

The applications of unprepared natural rubble, gravel and sand in civil engineering are quite limited. Most of these materials require preliminary treatment consisting in reducing the lumps (grains) to the required size, sorting the grains into several size fractions, and freeing the aggregate material from impurities.

To meet these requirements quarried rock has to be subjected to mechanical treatment, namely, to crushing, sorting (screening) and washing.

Depending on the kind of material and its designation, all the processes named or part of them may be employed in civil engineering; tens of millions of cubic metres of the materials in question are used annually, and their cost amounts to 8-15 per cent of the total cost of building materials.

Accomplishment of crushing, screening and washing requires the use of special crushing and sorting units and plants. The latter include conveying, crushing, washing and sorting machinery.

24. Conveyors

BELT CONVEYORS

Belt conveyors are employed for transporting loose materials, small-piece loads and concrete horizontally, or up- or downgrade.

Belt conveyors may be portable or stationary.

Portable conveyors are employed wherever it is necessary to transport small quantities of materials over a distance of from 5 to 20 m, *stationary conveyors*, where large quantities of materials have to be transported over distances of from 30 to 250 m.

The working unit of a belt conveyor is an endless *belt 2* (Fig. 79*a*). The upper part of the belt which carries the load is called the *loaded* or *tight side*, and the lower part, the *return* or *slack side*. The belt rounds pulleys *6* and *9*.

The *drive pulley 6* is rotated by a motor through a gear, chain or belt drive and draws the belt. The drive pulley is often the head pulley and is arranged at the end of the loaded side of the belt.

When the conveyor is equipped with a cotton duck rubber covered belt the drive pulley should have a diameter equal to the number of plies multiplied by a factor of from 120 to 150, and should be 100 mm wider than the belt. Driving pulleys may be straight faced or may have a small crown; the latter keeps the belt trained during operation, i.e., prevents it from shifting sideways.

The pulley *9* at the beginning of the loaded side is called the tail pulley and is usually also the take-up pulley, being part of the *take-up 1*.

The take-up serves to keep the belt at a constant tension.

Take-ups may be of the load or screw type.

Load-type take-ups are automatic in action: they may be horizontal (Fig. 79*b*) or vertical (Fig. 79*c*); the latter occupy

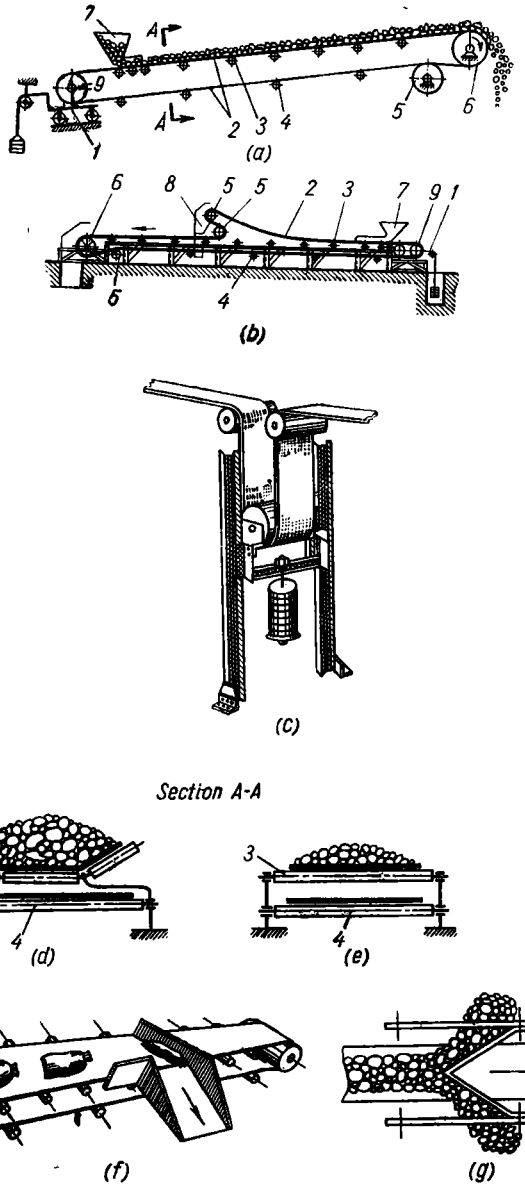


Fig. 79. Diagram of belt conveyor:

(*a*) with horizontal load-type take-up and head-pulley discharge, (*b*) ditto, with tripper, (*c*) vertical load-type take-up, (*d*) troughing idler, (*e*) straight idler, (*f*) one-sided discharging plow, (*g*) ditto, two-sided; *1*—take-up, *2*—endless belt, *3*—top idlers, *4*—bottom idlers, *5*—snub (*a*) and bend (*b*) pulleys, *6*—drive pulley, *7*—feed hopper, *8*—tripper, *9*—take-up pulley

less space. In the horizontal type the take-up pulley is mounted on skids or a truck, which are tensioned by a load fixed to a rope running over a pulley. Load-type take-up mechanisms are used in stationary conveyors.

Screw-type take-up mechanisms are essentially screws by means of which the bearings of the take-up pulley are moved back: this draws back the take-up pulley and tensions the belt. Screw-type take-up mechanisms are used in portable conveyors. In some types of take-up mechanisms special take-up pulleys are employed.

The *snub pulley 5* (Fig. 79*a*) increases the arc of contact between the drive pulley and the belt; bend pulleys *5* (Fig. 79*b*) are used when it is necessary to change the direction of the belt.

The belt is supported by *top 3* and *bottom* or *return 4 idlers*. Top idlers are spaced more closely than return idlers, because they support the loaded side of the belt. The idler spacing is as follows: 0.4-0.5 m at the feeding points, 1.1 to 1.5 m at other parts of the loaded side and 2.5 to 3 m on the return side.

Top idlers may be troughing or straight. *Troughing idlers* consist of several rollers at an angle to one another (Fig. 79*d*). These idlers bend the belt lengthwise into a trough, which almost doubles the cross-sectional area of the loose material conveyed compared to a flat belt (Fig. 79*e*).

The slack side of the belt is supported by the bottom idlers *4* which are always straight (Fig. 79*a*).

Idlers are made of 108- and 159-mm steel pipes or of cast iron; they are mounted predominantly on rolling contact bearings.

The conveyor is fed through a *hopper 7* (Fig. 79*a*, *b*) and is unloaded by discharging the material from the belt as it passes over the head pulley (Fig. 79*a*) or by means of *plows* (Fig. 79*f*, *g*) or *trippers 8* (Fig. 79*b*).

In the first case the material can be unloaded only at the head end of the belt, in the other two, at any point of the loaded side.

Feeders are used to ensure uniform and full loading of the belt.

The specifications of several types of belt conveyors are given in Table 10.

Table 10

Specifications of Belt Conveyors

Item	Portable					Stationary	
	T-45	T-144	T-80A	T-164	C-382	T-46A	T-47A
Capacity, t/hr	80	90	60	60	60	60	200
Maximum distance between pulley axes, m	15	15	10	10	5	40 | 80	240
Belt width, mm	500	500	400	400	400	500	650
Belt speed, m/s	1.2	1.6	0.8	1.0	1.0	1.31	2.0
Maximum height of unloading, mm	5,010	5,400	3,700	3,700	1,600	15,000 : 7,000	1,500 for 90-m length, 2,000 for 240-m length
Motor:							
power, kW	3.2	2.8	1.7	1.7	1.7	4.5 | 7.0	28
rpm	1,500	1,420	1,420	1,420	1,420	1,440	1,460
Overall dimensions, mm:							
length (max)	15,500	15,250	10,327	10,250	5,285	40,500 | 80,500	244,000
width	1,410	2,000	870	850	650	875	2,704
Weight, kg (maximum length)	1,130	1,074	396	435	305	1,600 2,730	17,016

T-45 Belt Conveyor (Fig. 80). The T-45 is a portable conveyor with its frame mounted on wheels. It is widely used for loading and unloading and in civil engineering.

The conveyor consists of the following main elements: belt *4*, drive pulley *6*, tail take-up pulley *1*, head pulley *12*, bend (auxiliary) pulleys *9*, electric motor *7*, belt drive *17*, pinion *15*, gear *8*, top idlers *10*, bottom idlers *5*, feed hopper *2*, traction wheels *18*, traction rollers *3*, axle *11*, winch *16*, scraper *13*, and arc *14*.

The conveyor *frame* consists of two parts: the lower (tail) supporting end *A* and the upper mobile end (jib) *B*.

The tail end of the frame is supported by the traction wheels *18* and the traction rollers *3*. The slope of the tail end is constant at 19°.

The supporting and mobile ends of the frame are hinged together so that the mobile end can be raised or lowered by rotating it about the hinge; this makes it possible to vary the unloading level between 0.5 and 5.01 m.

The *jib raising mechanism* (Fig. 81) enables the jib to be raised and lowered, and consists of a winch *11*, a rope *9*, and pulleys *5* arranged in pairs on the supporting end of the frame, and the jib. The rope is fastened to hook *10*, passes around one of the jib pulleys, runs to the pulleys on the supporting end of the frame, back to the second jib pulley and around it to the drum of winch *11*.

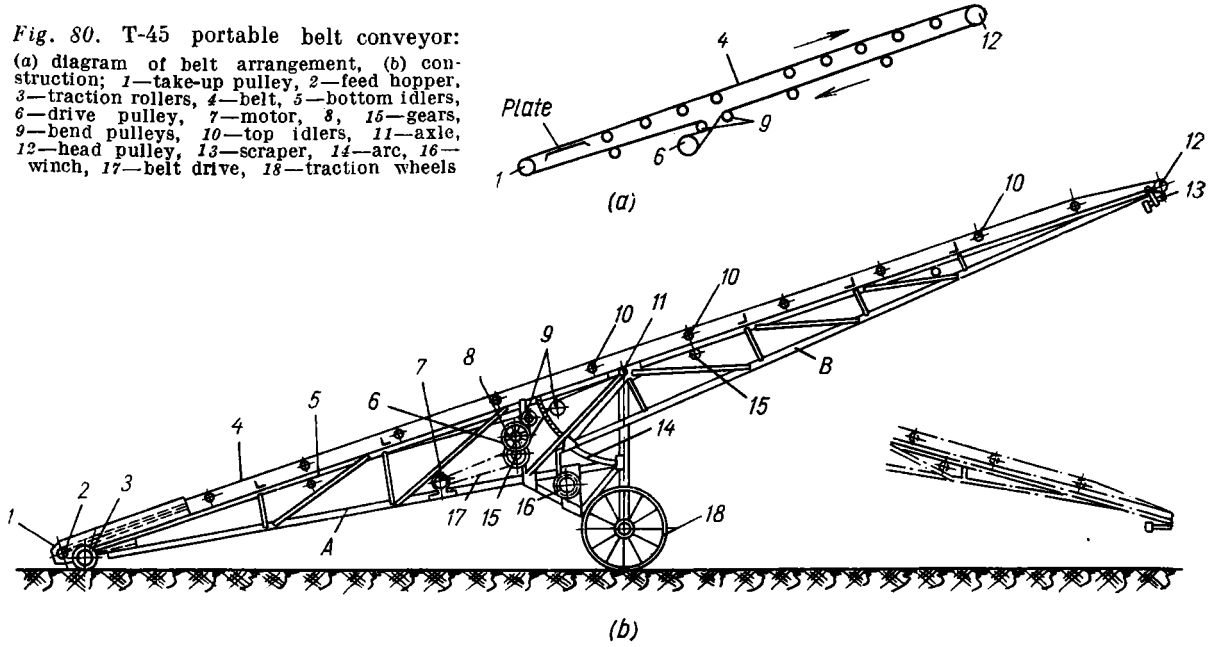
When the winch crank is rotated one way or the other the rope *9* winds on or off the drum raising or lowering the jib. The jib is indexed with pins *7* which are inserted in holes provided in the jib, in the corner plates *8* and in the supporting arcs *6*.

The *drive mechanism* for actuating the belt is arranged in the middle on the supporting end of the conveyor frame and consists of a drive pulley *1*, electric motor *2*, two bend pulleys *3*, a belt drive *4*, and a set of gears *12*.

The screw-type take-up (Fig. 82) tensions the belt. The mechanism operates as follows: turning the handwheel *1* rotates the take-up screws *2* to which it is geared, and these shift bearings *3* along guides on the frame together with the axle *4*, take-up pulley *5*, and belt.

The *top idlers* (Fig. 83*a*) support the loaded side of the belt; they consist of three rollers each, forming a trough-

Fig. 80. T-45 portable belt conveyor: (*a*) diagram of belt arrangement, (*b*) construction; *1*—take-up pulley, *2*—feed hopper, *3*—traction rollers, *4*—belt, *5*—bottom idlers, *6*—drive pulley, *7*—motor, *8*, *15*—gears, *9*—bend pulleys, *10*—top idlers, *11*—axle, *12*—head pulley, *13*—scraper, *14*—arc, *16*—winch, *17*—belt drive, *18*—traction wheels



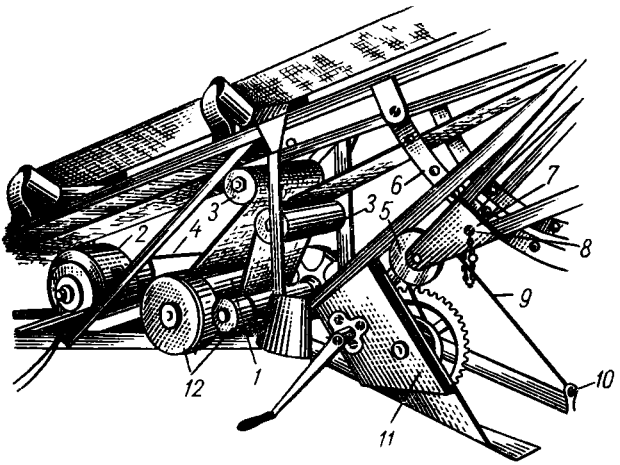


Fig. 81. Jib raising and drive mechanisms of T-45 conveyor:
1—drive pulley, *2*—motor, *3*—bend pulleys, *4*—belt drive, *5*—pulleys, *6*—arc, *7*—pin, *8*—corner plate, *9*—rope, *10*—hook, *11*—winch, *12*—set of gears

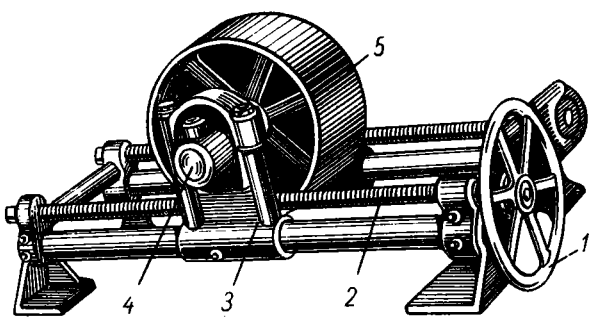


Fig. 82. Screw-type take-up of T-45 conveyor:
1—handwheel, *2*—take-up screws, *3*—bearing, *4*—axle, *5*—take-up pulley

shaped support. Each idler has the following parts: middle roller *9*, side rollers *3*, housing *8* for ball bearings *10*, axle *11*, supports *12* and *2*, strip *13*, bolts *1*, thrust covers *6*, outside covers *4*, felt rings *5*, and screws *7*.

The *bottom idlers* (Fig. 83*b*) support the return side of the belt; these idlers have one straight roller each. They include the following parts: axle *11*, bearing housing *8*, thrust covers *6*, outside covers *4*, felt rings *5*, and screws *7*.

The *feed hopper* (Fig. 84) serves to feed loose materials to the tail end of the conveyor. The hopper *1* of sheet steel is fastened to the receiving pan *2* by means of dowels *4* and eyes *3*. The skirtboards *6* guide the load on to the belt *5*. Rubber strips *7* are fixed to the lower edges of the receiving pan and the skirtboards.

For loading piece materials loading tables are installed from which the load is shifted on to the conveyor belt.

T-144 Belt Conveyor (Fig. 85). This is a portable conveying machine having a length of 15 m between drive and take-up pulleys. The conveyor is furnished with a cotton fabric rubber coated belt 500 mm wide. It is actuated by an electric motor mounted on the frame.

To make it portable the conveyor is mounted on a two-wheel chassis.

The main components of the conveyor are: lower frame girder *11*, upper frame girder *14*, chassis with supports *1*, *3* and wheels *2*, winch *6* of frame lifting mechanism, drive pulley *15*, drive mechanism *16* with electric motor, take-up pulley *8* with take-up, top idlers *10*, bottom idlers *5*, belt *12*, and feed hopper *9*.

The conveyor *frame* consists of two girders, the lower *11*, and the upper *14* which are bolted together with bolts *13*. The girders are made of section steel. During operation the lower girder rests with its leg *7* on the ground.

To put the conveyor in its traction position (Fig. 86) the belt is removed, the girders are unbolted and arranged side by side on the chassis, after which the conveyor is hitched to a lorry.

In its traction position the conveyor has the following overall dimensions: length 7.7 m, width 2 m, height 1.1 m, distance between lowest projecting part of conveyor and ground (clearance) 0.28 m.

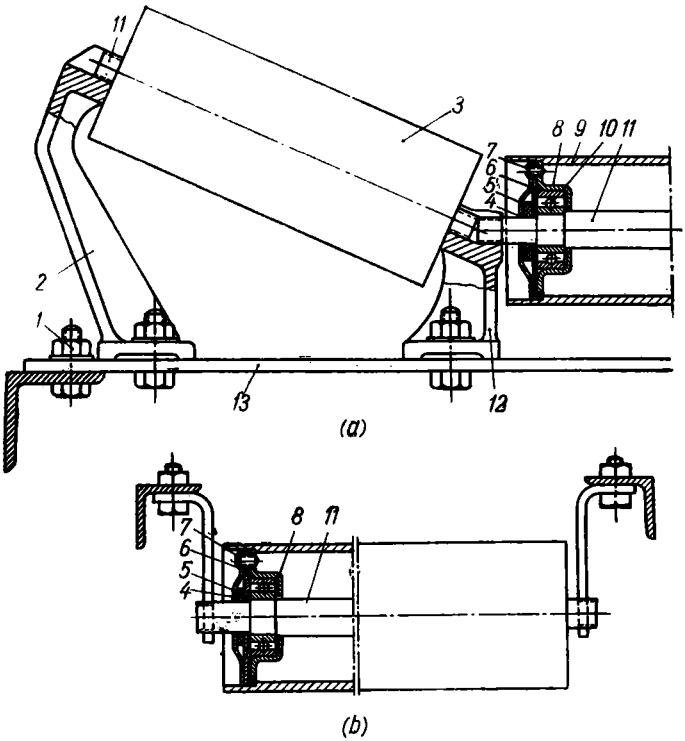


Fig. 83. Idlers of T-45 conveyor:

(*a*) top, (*b*) bottom; *1*—bolt, *2*, *12*—supports, *3*—side roller, *4*—outside cover, *5*—felt rings, *6*—thrust cover, *7*—screw, *8*—bearing housing, *9*—middle roller, *10*—bearing, *11*—axle, *13*—strip

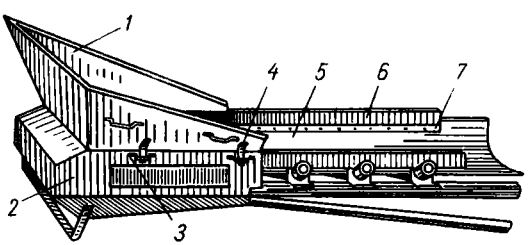


Fig. 84. Feed hopper of T-45 conveyor:

1—hopper, *2*—pan, *3*—eyes, *4*—dowels, *5*—belt, *6*—skirtboards, *7*—rubber strip

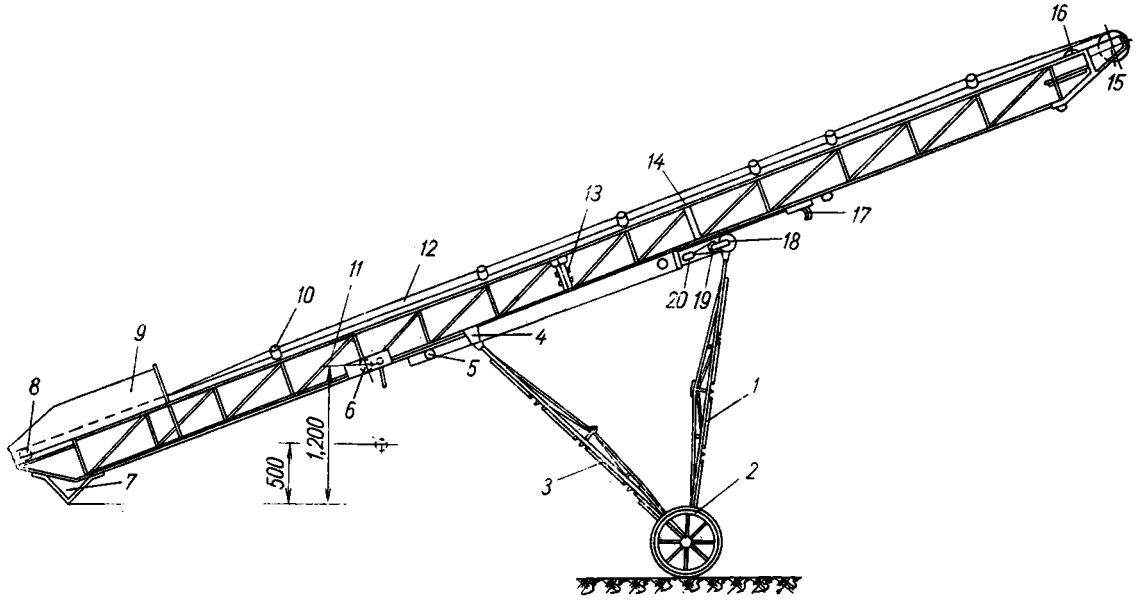


Fig. 85. General view of T-144 portable conveyor:

1, *3*—supports, *2*—wheel, *4*—hinge, *5*—bottom idlers, *6*—winch, *7*—leg, *8*—take-up pulley, *9*—feed hopper, *10*—top idlers, *11*—lower frame girder, *12*—belt, *13*—bolts, *14*—upper frame girder, *15*—drive pulley, *16*—drive mechanism, *17*—stops, *18*—rollers, *19*, *20*—pulleys

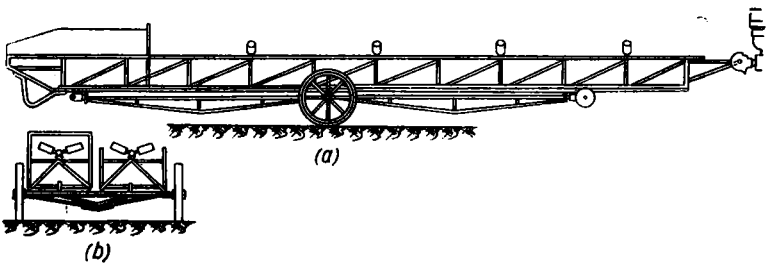


Fig. 86. T-144 conveyor in traction position:
(*a*) side view, (*b*) rear view

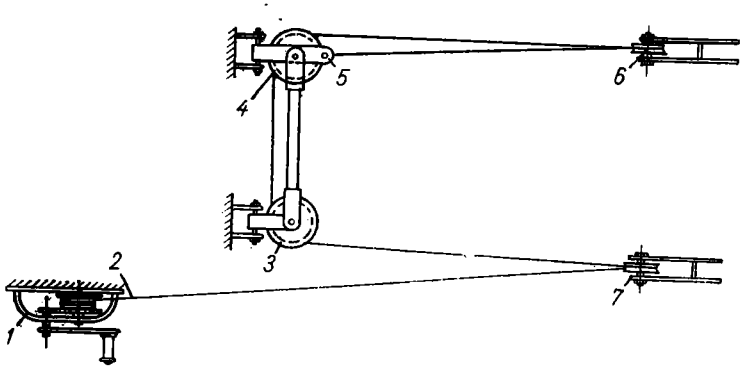


Fig. 87. Rope reeving diagram of T-144 conveyor:
1—winch, *2*—wind-in end of rope, *3*, *4*, *6*, *7*—pulleys, *5*—fixed end of rope

The conveyor *chassis* (see Fig. 85) has an axle with two steel wheels. To this axle are hinged the lower ends of the supports *1* and *3* which are made in the form of steel structures. Support *1* has two rollers *18* at its top end, on which the upper girder *14* of the conveyor frame rests; the top end of support *3* is connected to the lower girder *11* with a hinge *4*.

During traction the supports are turned about the chassis axle into a horizontal position.

The *frame lifting mechanism* of the conveyor (Fig. 87) consists of a winch, a steel rope and four pulleys *3*, *4*, *6*, and *7*. The forks of pulleys *6* and *7* are hinged to the rollers *18* of stand *1* (see Fig. 85); the forks of pulleys *3* and *4* (Fig. 87) are similarly connected to the upper frame girder.

The rope of the lifting mechanism is reeved as follows: one end *2* of the rope is made fast in the drum of winch *1*, from which the rope passes over pulley *7* of support *1*, then over pulleys *3* and *4* fixed to the upper girder and over pulley *6* of stand *1*. The other end *5* of the rope is fastened to the fork of pulley *4* on the upper girder.

The lifting mechanism works as follows. The conveyor frame (see Fig. 85) rests with its upper girder *14* on the rollers *18* of support *1*. The rollers are connected through their forks with pulleys *19* (or *6* and *7* on Fig. 87).

When the winch drum is rotated to wind the rope on to the drum, the hinged support rotates counterclockwise about the chassis axis and rollers *18* (see Fig. 85) raise the frame; when the rope winds off the drum the frame comes down because its weight presses against the rollers rotating the support clockwise.

The stops *17* on the bottom member of the upper girder limit the travel of the rollers.

In Fig. 85 the frame is in its highest position—5.5 m, and at its maximum slope of 20° to the horizontal.

The *top idlers 10* consist of two rollers forming a trough-shaped support.

The *bottom idlers 5* consist of one straight roller each. Both kinds of rollers are mounted on ball bearings.

The *drive mechanism 16* is arranged on the head part of the conveyor frame; it consists of an electric motor, a reducing

gear train and a chain transmission to the head pulley shaft.

The *screw-type take-up mechanism* is arranged at the end of the lower girder where the take-up tail pulley *8* is situated. The mechanism enables a take-up travel of 400 mm.

The sheet steel *feed hopper 9* for loading the conveyor with loose materials is situated at the end of the lower girder above the tail pulley.

C-382 Portable Belt Conveyor (Fig. 88). The C-382 portable belt conveyor 5 m long is intended for conveying loose and piece materials horizontally and at an angle of up to 20° at auxiliary construction plants.

The conveyor consists of a welded latticework frame mounted on two traction wheels; a rubber belt; drive and take-up pulleys; troughing idlers for the upper, loaded side of the belt; straight idlers for the lower, return side of the belt, and a drive consisting of an electric motor, a reducing gear train and a chain transmission.

Belt slack is taken up by means of the take-up pulley whose axle is supported by movable bearings adjusted by screws. Rollers and pulleys are furnished with ball bearings. The conveyor has a feed hopper.

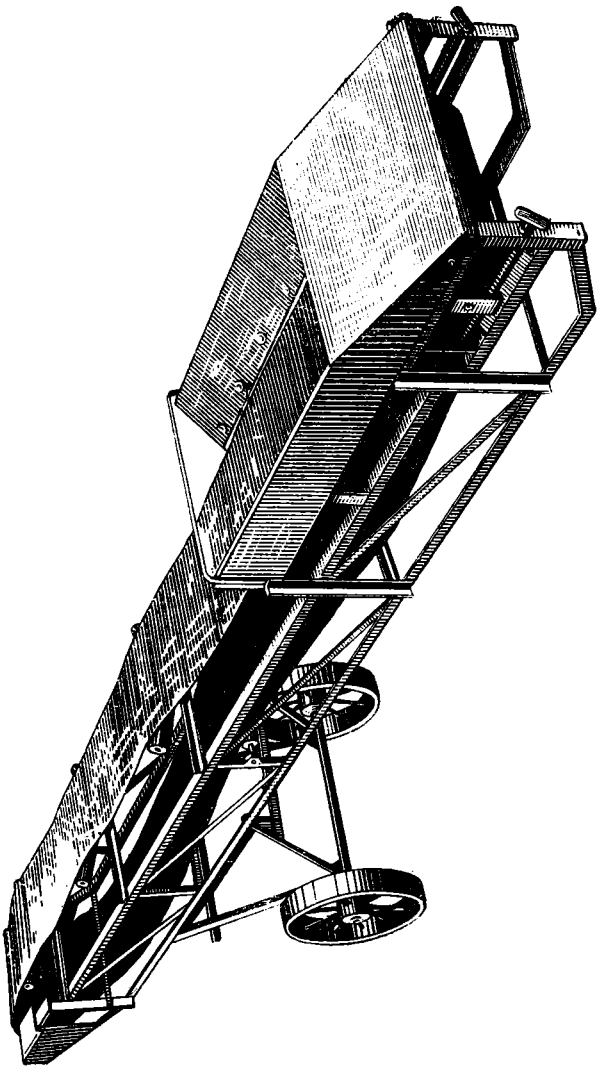
The conveyor frame is an angle iron welding.

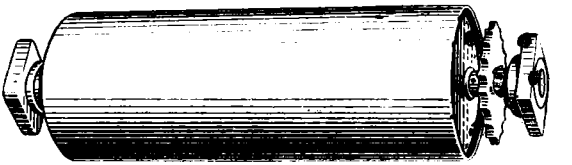
The *drive* and *take-up pulleys* are either steel weldings (Fig. 89*a*) or are built up of a steel framework lined with wood (Fig. 89*b*). The wood lining improves the contact between belt and pulley, reducing wear of the former.

The drive pulley is rotated by motor *1* (Fig. 90) through a two-step reducing gear *2* and a chain transmission with its driving sprocket *3* seated on the output gear shaft, and its driven sprocket, on the drive pulley shaft.

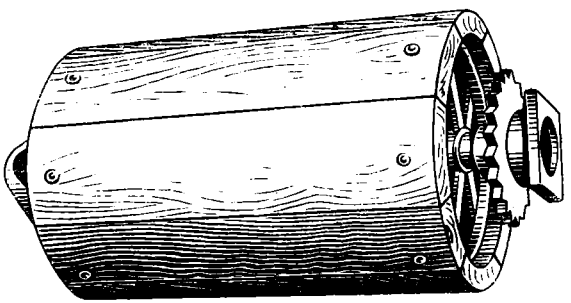
The motor and drive are installed inside the frame between the sides of the belt. This arrangement enables the belt to be removed from the drive pulley. To do so it is only necessary to remove two bottom idlers and move aside the take-up pulley.

The *top idlers* are troughed (Fig. 91*a*); the return side of the belt is supported by straight rollers (Fig. 91*b*). The idlers are made of pipe lengths with ball bearings mounted inside their bodies.





(a)



(b)

Fig. 89. Conveyor drive pulleys:
(*a*) welded steel pulley, (*b*) wood-lined pulley

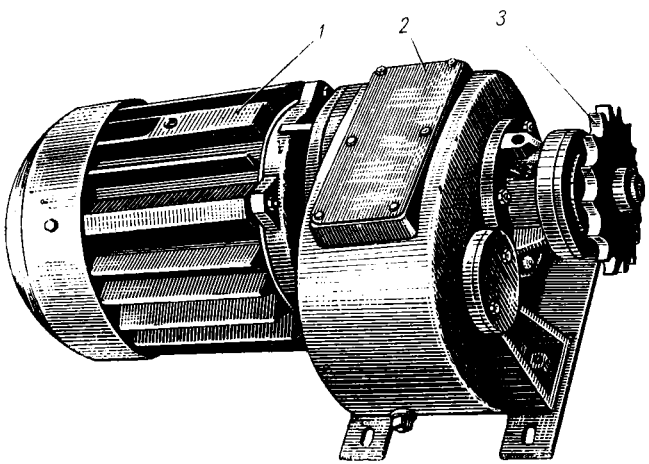


Fig. 90. Conveyor drive:
1—motor, *2*—reducing gear, *3*—driving sprocket

The conveyor has two *scrapers*, one for cleaning the outer surface of the belt, and the other, an auxiliary one, for cleaning its inner surface.

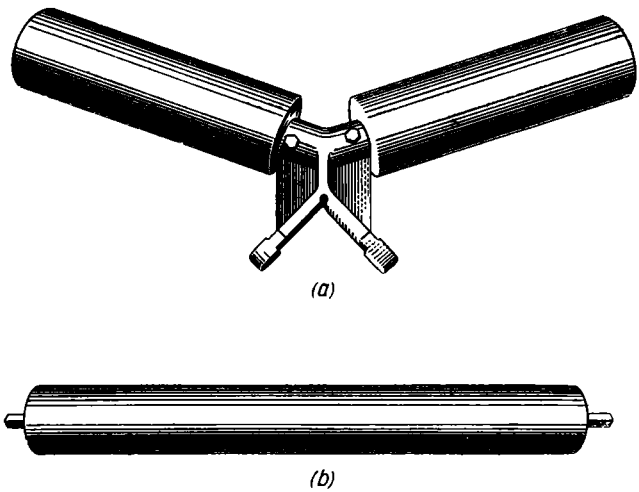


Fig. 91. Conveyor idlers:
(*a*) top, troughing, (*b*) bottom, straight

The *removable feed hopper* is clamped to the upper frame member. Just below the feed hopper the belt is supported by a sheet of steel to prevent sagging.

The *wheels* of the C-382 are clamped to the lower frame member.

Installation of Portable Conveyors. Portable conveyors are delivered to the working site assembled (only the belt, motor and feed hopper are removed). Before installation check to see whether all the parts have arrived and whether they are in good condition.

Place the conveyor wheels on wooden pads.

The conveyor frame should be assembled so that the wheel axis is horizontal; check this with a level.

Then put the belt and motor in place, lay the power transmission lines, connect the motor and install the feed hopper and tripper.

After installing grease the conveyor and make a test run.

T-46A Belt Conveyor (Fig. 92). This conveyor is employed as a permanent (stationary) unit for conveying materials horizontally up to 80 m and lifting them to a height of up to 7 m with the full length of the frame. The conveyor is used at construction sites, quarries and mortar and concrete plants.

The main components of the conveyor are as follows: electric motor *7*, belt drive *13*, gear shaft *5*, spur gears *3*, *4*, drive pulley *1* and its shaft *2*, take-up pulley *10* and its axle *9*, take-up *11*, top idlers *8*, bottom idlers *6*, belt *12*, and frame sections *14*.

The belt is actuated by motor *7* through belt drive *13*, spur gears *3* and *4*, and drive pulley *1*.

The conveyor *frame* consists of separate sections 2.5 m long. The frame sections (Fig. 93) have the following design: hooks *2* are welded to one end of the longitudinal angle iron *1*, and screw clamps *3* to the other; the sections are connected to each other by means of these clamps. The upper member of each section has holes drilled in it for the top idlers and one bottom idler.

The distance over which materials are transported by means of this conveyor may be reduced by eliminating one or more sections. Part of the sections may be installed level, and others at a grade.

If the height of lift has to be more than 7 m, two frame sections must be eliminated for each metre of increased height of lift.

The top and bottom *idlers* are of the same design as in the T-45 unit.

The *drive mechanism* (see Fig. 92) is situated near the head of the conveyor, the shafts of this mechanism being mounted in ball bearings on a welded angle iron frame. The drive pulley is made of cast iron.

A *back set* (Fig. 94) is installed on the frame next to the drive pulley. This device serves to stop the pulley if the motor stops with the conveyor inclined, and the loaded belt tends to reverse due to gravity. As long as the pulley *2* and the belt *3* are rotating and moving respectively in the right direction (indicated by the arrow), the free end of the check band *1*, the other end of which is fastened to the frame, will be drawn away from the pulley by the belt. If the pulley

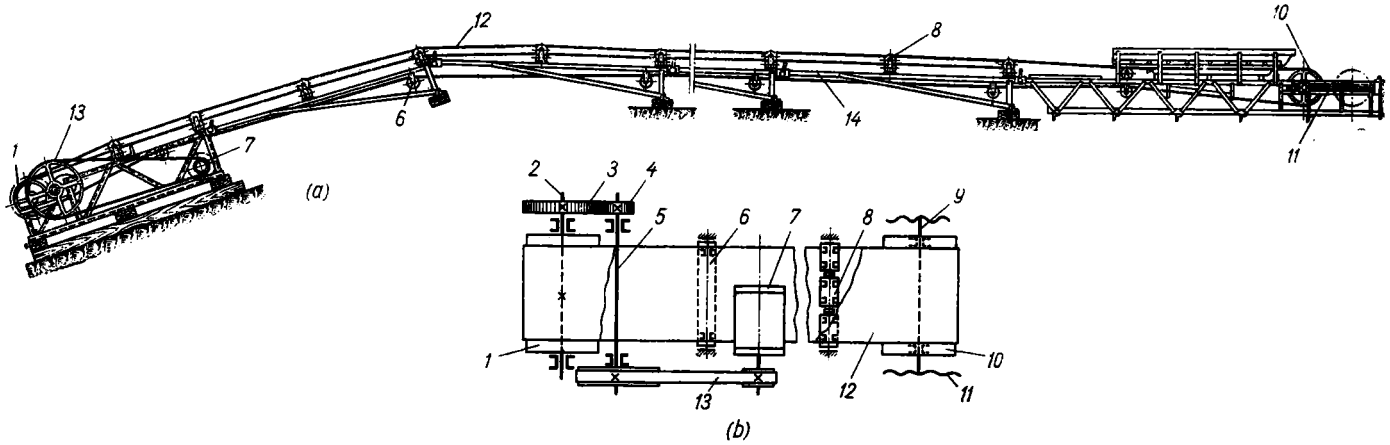


Fig. 92. T-64A belt conveyor:

(*a*) construction, (*b*) gear train diagram; *1*—drive pulley, *2*, *5*—shafts, *3*, *4*—gears, *6*, *8*—idlers, *7*—motor, *9*—axle, *10*—take-up pulley, *11*—take-up, *12*—belt, *13*—belt drive, *14*—frame

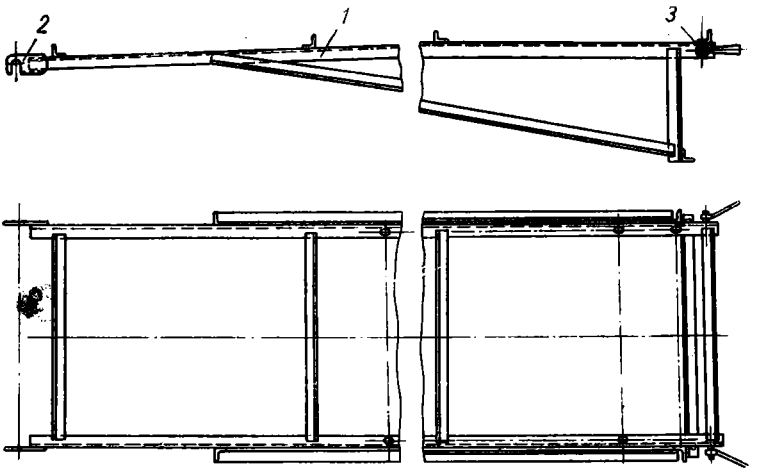


Fig. 93. Intermediate frame section of T-46A:
1—angle iron, *2*—hooks, *3*—clamps

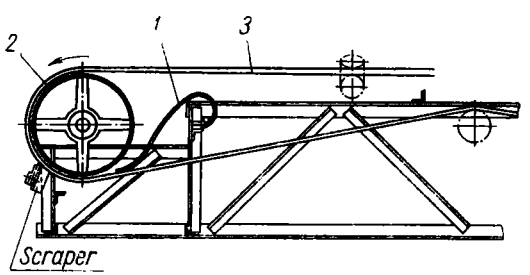


Fig. 94. Diagram of back set and scraper installation on T-46A: conveyor:
1—check band, *2*—pulley, *3*—belt

begins to rotate, and the belt to move, in the opposite direction the end of check band *1* gets caught between the belt *3* and the pulley *2*, stopping the pulley and the conveyor belt.

The *take-up* (Fig. 95) consists of a frame and tensioning screws; installed on the take-up frame *1* are straight idlers *2*, a scraper *3*, a feed pan *4* and a plate *5*. The frame of the take-up is a welded angle iron structure.

The take-up (Fig. 96) has the following design. The ends of the take-up pulley axle *1* fit into holes in the sliders *2*, which, besides these, have other holes for tensioning screws. Nuts *3* are inserted in the slider grooves. When the screws *4* are rotated they make the nuts *3* ride along them carrying the sliders together with the pulley along the legs of the guide angles.

The take-up pulley is made of cast iron. Its hub *6* rests on ball bearings *5* on the axle *1*; *7* is the bearing cover and *8* its felt seal.

Installing the Stationary Conveyor. This conveyor is assembled at the site of its operation.

As delivered from the manufacturing plant the conveyor is dismantled into the following parts: drive, take-up, sections with bottom idlers, top troughing idlers, belt, and motor.

Before assembling and installing the conveyor, plan out its site. Stretch a cord along the conveyor site axis and lay out sites for the take-up and drive; outline the foundations, the arrangement of the pulley axes and the points where the drive and take-up are to be fastened.

The drive and take-up pulleys must be installed strictly horizontal.

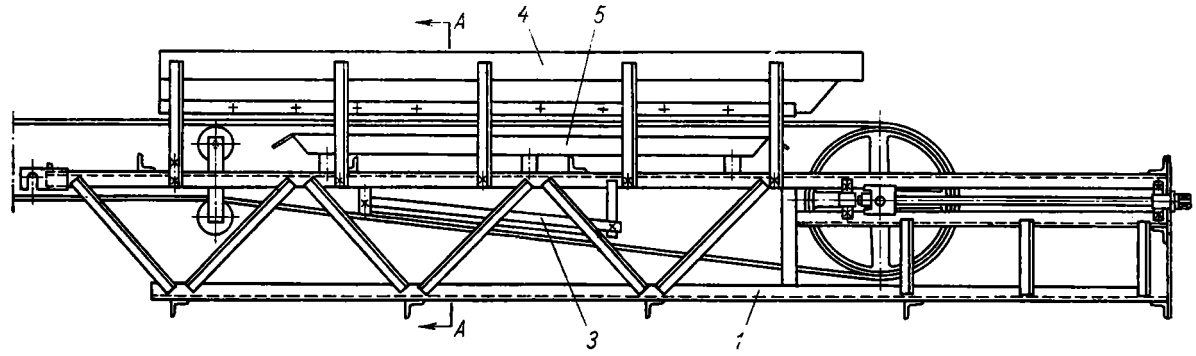
Lay off the points for the supports of the intermediate sections and place a wooden pillow-support in each; if the conveyor is level all these supports must be in the same horizontal plane.

The conveyor may be set at a grade either along an inclined plane, say, up or down an embankment, or along a level plane. In the former case the sections are laid on pillows placed on the embankment surface and made fast to prevent sliding; in the latter, they are laid on special supports spaced 2.5 m apart.

Install the top idlers on the sections and check to see that their axes are at right angles to the conveyor centre line; then put the belt in place.

Install the motor on the drive mechanism frame; make sure the motor shaft is parallel to the drive mechanism shaft and the pulleys are at an equal distance from the conveyor centre line.

In the process of assembly inspect and grease all the mechanisms of the conveyor.



Section A-A

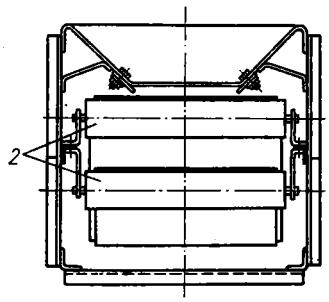


Fig. 95. Diagram of T-46A conveyor take-up:
1—frame, *2*—idlers, *3*—scraper, *4*—feed pan, *5*—plate

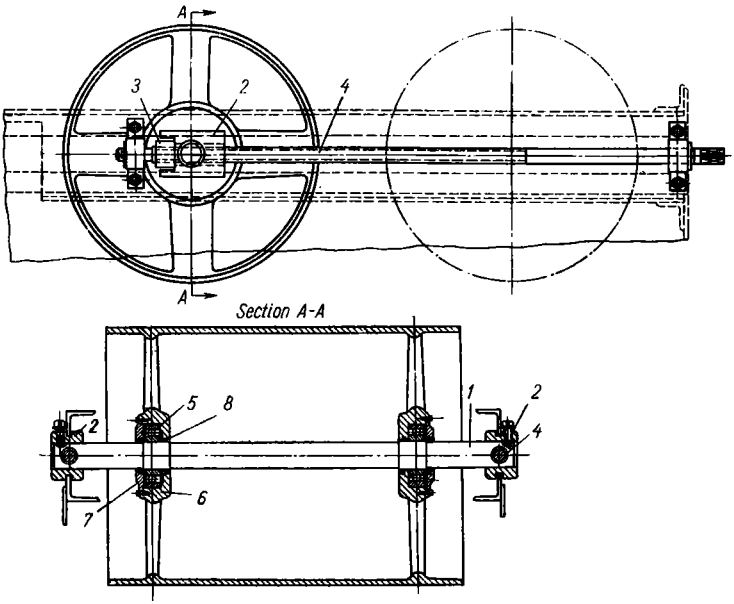


Fig. 96. T-46A conveyor take-up:
1—axle, *2*—slider, *3*—nut, *4*—screw, *5*—bearing, *6*—hub, *7*—cover, *8*—sea-

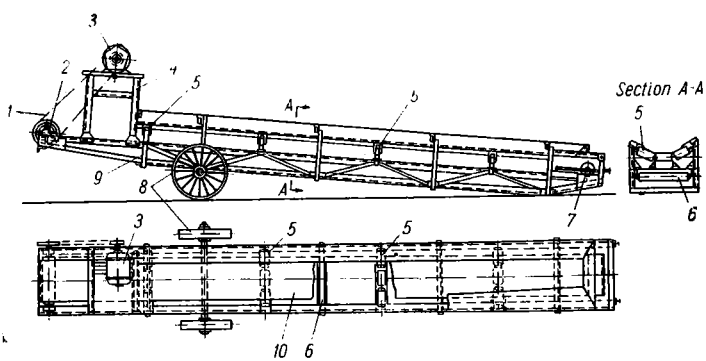


Fig. 97. T-44 feeder-conveyor:
1—belt drive, *2*—drive pulley, *3*—motor, *4*—support, *5*—top idlers, *6*—bot tom idlers, *7*—take-up, *8*—two-wheel carriage, *9*—frame, *10*—belt

T-44 Feeder-Conveyor (Fig. 97). This conveyor is used for feeding stationary conveyors, loading loose and small-piece materials into transport vehicles, for continuous and uniform loading of several types of contractor's machinery during their operation.

The chief elements of the feeder-conveyor are: frame *9*, two-wheel carriage *8*, belt *10*, top *5* and bottom *6* idlers, drive pulley *2*, motor *3*, belt drive *1*, and screw-type take-up *7*.

The *frame 9* is a welded structure or is made of angle iron and rests on a two-wheel carriage *8*. The motor is bolted to a steel support *4*, the uprights of which are welded to the conveyor frame.

The *drive mechanism* (Fig. 98) has the following construction. The rotation of the motor *3* is transmitted to the drive pulley *6* by a belt drive consisting of a driving pulley *4* seated on the motor shaft, a driven pulley *1* seated on the shaft *5* of conveyor drive pulley *6* and a drive belt *2*. The conveyor drive pulley shaft is supported by ball bearings *7*.

The *take-up* (Fig. 99) is designed as follows: the take-up pulley *15* rotates on axle *14* the ends of which are fixed rigidly in the holes of sliders *6* with set screws *7*. The sliders have grooves in their bottoms which fit on guide rails *3*; the latter are bolted (bolts *2*) to the main frame *1*. The sliders have square nuts *5* inserted in them, which ride screws *4*. The sliders and the pulley are shifted by rotating these screws.

Shifting the pulley creates the required tension in the conveyor belt. The take-up pulley *15* rotates in ball bearings *12* arranged on the axle *14*, the bearing housings *13* being welded to the pulley. The ball bearings are closed on the outside with a thrust cover *11* and an outer cap *9*, a felt ring *8* being inserted between the cover and the cap. The cover and cap are screwed to the bearing housing (screws *10*).

The *top* and *bottom idlers* are of the same design as those of the T-45 conveyor.

A *scraper* (Fig. 100) for removing adhering material from the belt surface is installed below the drive pulley. The rubber strip *1* of the scraper is clamped between a strap *2* and the plank of bracket *4* with bolts *3*. The bracket is suspended

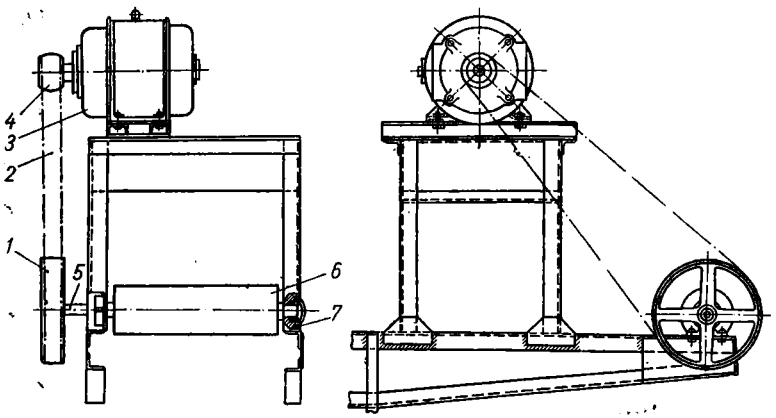


Fig. 98. T-44 feeder-conveyor drive mechanism:
1—driven pulley, *2*—drive belt, *3*—motor, *4*—driving pulley, *5*—shaft, *6*—conveyor drive pulley, *7*—ball bearings

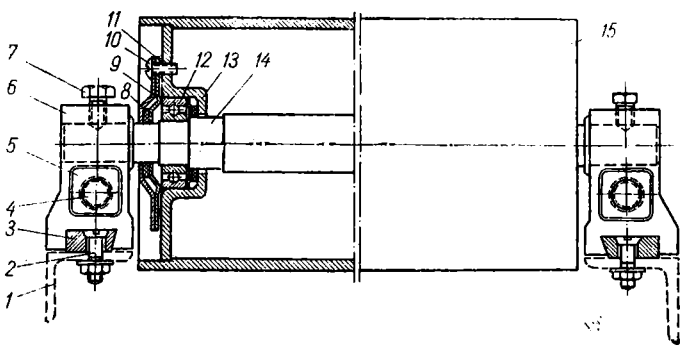


Fig. 99. T-44 feeder-conveyor take-up:
1—frame, *2*—bolt, *3*—guide rail, *4*, *7*, *10*—screws, *5*—nut, *6*—slider, *8*—ring, *9*—outer cap, *11*—thrust cover, *12*—bearing, *13*—bearing housing, *14*—axle, *15*—take-up pulley

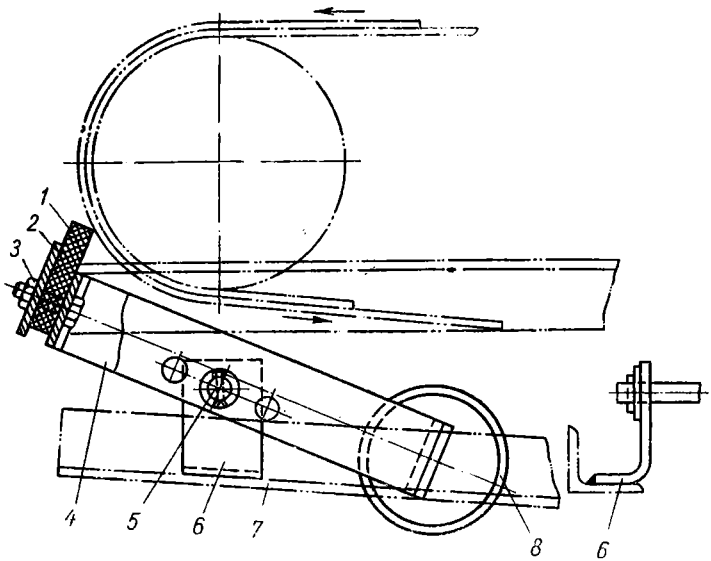


Fig. 100. T-44 conveyor belt cleaning scraper:
1—rubber strip, *2*—strap, *3*—bolt, *4*—bracket, *5*—axle, *6*—angle irons, *7*—conveyor frame, *8*—counterweight

by axle *5* which is fixed in angles *6* welded to the conveyor main frame *7*. A counterweight *8* is suspended from the end of bracket *4* to press the bracket with its rubber strip against the belt.

APRON FEEDERS

Apron feeders are used for feeding run-of-mine materials to primary crushers.

Apron feeders are put out in heavy- and light-duty versions. Heavy-duty feeders are designed to take materials of lump sizes up to 1,300 mm. The construction of these machines allows for dropping of the lumps fed to them from a considerable height. Light-duty apron feeders are used for materials of up to 300 or 400 mm lump size under relatively mild operating conditions.

The specifications of heavy- and light-duty feeders are given in Tables 11 and 12.

Table 11

Specifications of Heavy-Duty Apron Feeders Manufactured by Novo-Kramatorsk Works

Item	Feeder size, mm				
	1,200× ×5,600	1,200× ×6,000	1,200× ×8,700	1,500× ×4,000	1,800× ×12,000
Apron width, mm	1,200	1,200	1,200	1,500	1,800
Distance between sprocket centres, mm	5,600	6,000	8,700	4,000	12,000
Speed, m/s	0.05	0.11	0.05	0.05	0.05
Lump size of material handled, mm	up to 600	up to 600	up to 600	up to 500	up to 900
Capacity, m^3/hr	up to 120	up to 180	up to 120	—	up to 180
Motor ratings:					
power, kW	21.5	36	29	11.5	29
rpm	1,475	1,475	1,450	1,460	1,480
Gear ratio of reducer	280.5	126	280.5	280.5	284.4
Sprocket rpm	1.5	3.6	1.5	1.5	—
Overall dimensions, mm:					
length	8,026	8,576	11,270	6,576	14,526
width	5,268	5,580	5,336	5,593	6,081
height	2,346	2,346	2,346	2,346	2,346
Weight, kg	43,600	48,500	60,900	40,600	89,600

Heavy-Duty Feeder (Fig. 101). The parts of the feeder are arranged in the frame *1*. The lumps are transported by an endless moving apron *2* made up of swaged steel links with steel pans welded to them.

The loaded side of apron *2* rests on supporting idlers *3*, and the return side, on bottom idlers *4*. The slack of the apron is taken up by means of a screw-type take-up *5* with self-aligning bearings.

Table 12

Specifications of Light-Duty Apron Feeders

Item	Kotlyakov Works		Vyksun Works	
	1,000× ×3,000	1,200× ×3,000	CM-97A	CM-59A
Apron width, mm	1,000	1,200	800	1,000
Distance between sprocket axes, mm	3,000	3,000	6,000	3,000
Width between skirtboards, mm	850	1,050	—	—
Height of skirtboard, mm	260	260	—	—
Speed, m/s	0.025-0.15	0.025-0.15	0.032-0.06	0.08-0.16
Maximum lump size, mm	400	400	—	—
Recommended slope, deg	—	—	up to 20	up to 15
Motor ratings:				
power, kW	4.3	4.3	4.5	4.5
rpm	1,500	1,500	1,440	1,440
Gear ratio of reducer	30.3	30.3	31.5	21.5
Overall dimensions, mm:				
length	4,650	—	7,120	4,120
width	2,920	—	2,630	2,800
height	1,130	—	1,300	1,460
Weight, kg	4,472	4,808	9,200	6,240
Capacity (approx.), t/hr	40-200	45-270	42-80	120-240

The feeder apron is wrapped around drive and take-up sprockets with hard-alloy plated teeth for better resistance to wear.

The drive sprockets are rotated by the motor through reducer *7* and gearing *9*. The reducer consists of three pairs of gears with their shafts supported on roller and ball bearings. The gearing *9* consists of two gears. Feeders with aprons 1,800 mm wide are equipped with helical gears, while the smaller sizes have spur gears.

Rotation is transmitted from the motor to the reducer input shaft and from the reducer output shaft to the gearing

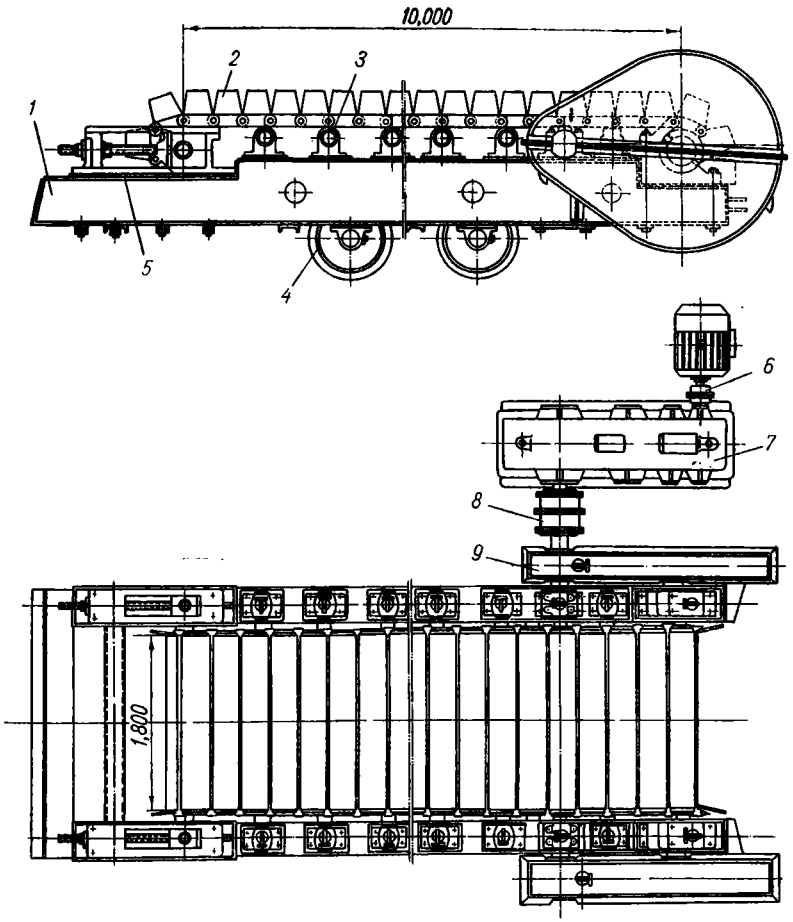


Fig. 101. Heavy-duty feeder:
1—frame, *2*—apron, *3*, *4*—idlers, *5*—take-up, *6*, *8*—claw clutches, *7*—reducer, *9*—gearing

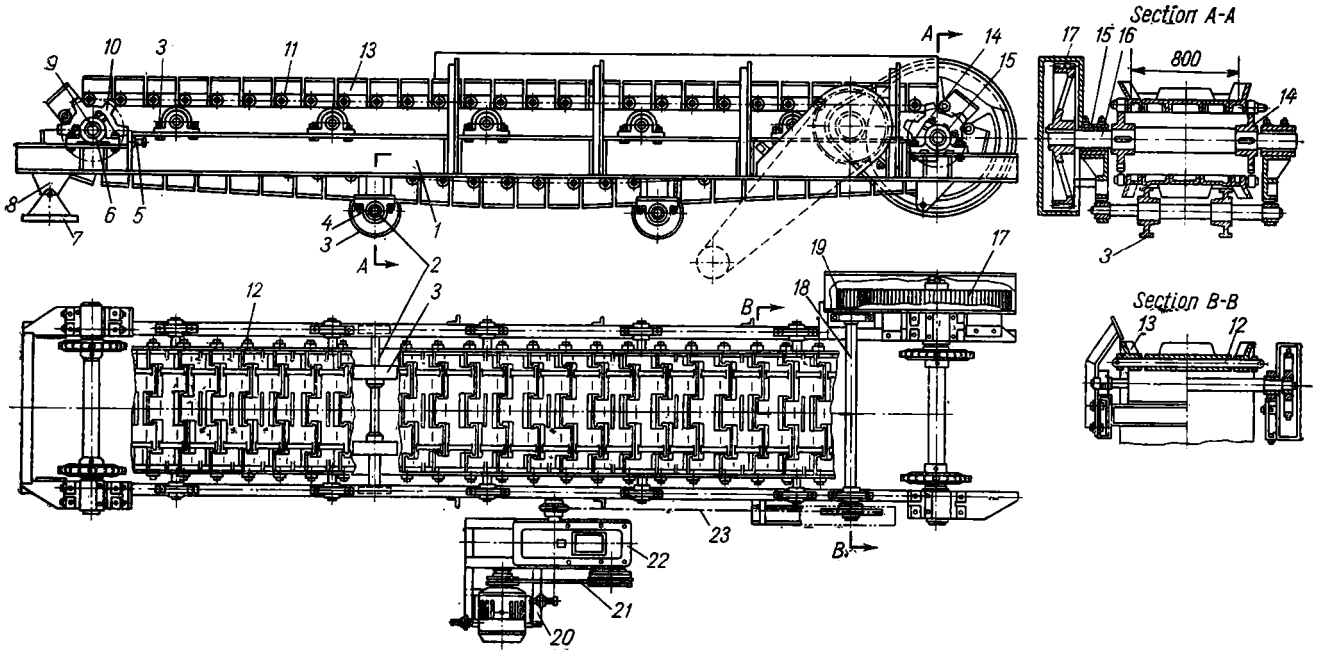


Fig. 102. Light-duty feeder:

1—frame, *2*, *9*, *16*, *18*—shafts, *3*, *7*—idlers, *4*, *6*, *15*—bearings, *5*—take-up, *8*—bracket, *10*, *14*—sprockets, *11*—rollers, *12*—studs, *13*—pans, *17*, *19*—gears, *20*—motor, *21*—V-belt drive, *22*—reducer, *23*—chain drive

input shaft through claw clutches *6* and *8* the use of which makes a skew of up to 1.5° between the coupled shafts permissible and allows for maximum axial displacement of the shafts. The sleeve-bearing inserts are made of antifriction cast iron and are lubricated by filling special "pockets" made in the bearings with oil impregnated wool combings.

Feeders 6 m long or more are installed at an incline of 15° to the crusher.

The back wall of the feeder hopper should have a slope of 55° and the side walls, 48°; to prevent clogging of the hopper outlet opening with lumps of material the height of the opening should be twice the size of the largest lump.

Light-Duty Feeder (Fig. 102). The operating principle of this feeder is the same as that of the heavy-duty feeder. It also has an endless conveying apron made up of welded steel pans *13* connected by studs *12* with rollers *11* on their ends, which fit into the tooth spaces of the drive *14* and take-up *10* sprockets. The drive sprockets *14* are seated on shaft *16* and the take-up sprockets *10* on shaft *9*. These shafts are supported by sleeve bearings. The loaded and return sides of the apron are supported by idlers *3* which are essentially rollers seated on shafts *2*. The latter rotate in sleeve bearings *4*, *6*, and *15*. The apron is tensioned by means of a screw-type take-up *5*.

The drive sprockets *14* are rotated by an electric motor *20* through V-belt drive *21* and reducer *22*, chain drive *23* transmitting the rotation to shaft *18* of a gear drive consisting of gears *17* and *19*, which transmit the rotation to the drive sprockets. The steel frame *1* of the feeder has a bracket *8* hinged to a support *7*. This makes it possible to change the incline of the feeder.

BUCKET ELEVATORS

Bucket elevators are used for moving loose (sand, cement) and lump (crushed stone, gravel, slag) materials vertically or at a steep incline. In this respect we distinguish between vertical and inclined elevators. The former include the T-50 and T-52 models. The buckets of the T-50 are carried by an endless belt, while those of the T-52 are fastened to an endless vertically moving haulage chain. The latter are represented

by the T-51 and T-56 models. The buckets of the T-51 elevator are carried by one, and of the T-56, by two chains moving along an incline at 60°.

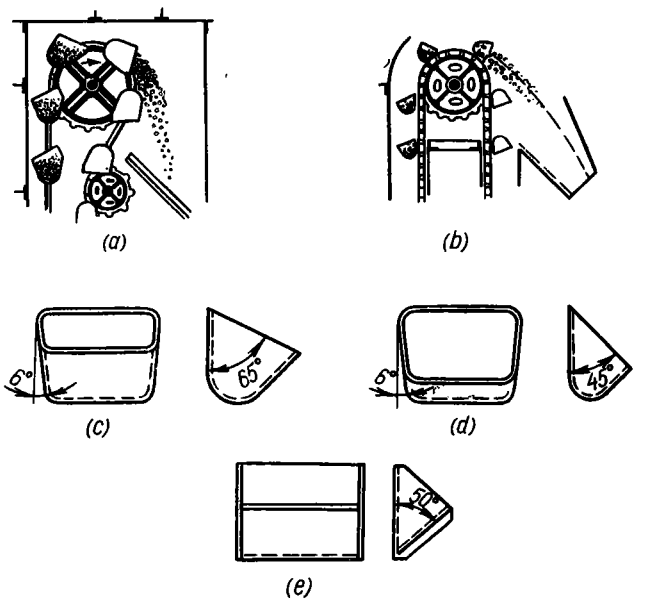


Fig. 103. Methods of discharge and types of buckets:
(*a*) low-speed discharge, (*b*) high-speed discharge, (*c*) deep bucket, (*d*) shallow bucket, (*e*) V-shaped bucket

Elevators are employed at mortar-mixing units, at mortar and concrete plants, at crushing and sorting plants, etc.

The operation of an elevator is schematically as follows. The endless rubber belt or haulage chain to which the buckets are fastened runs round an upper drive pulley or sprocket and a lower take-up pulley or sprocket.

On passing round the lower pulley the buckets dig into the loose material, and on passing round the upper pulley they turn over and discharge it. Bucket discharge at low speeds is illustrated in Fig. 103*a*, and at high speeds, in Fig. 103*b*.

The buckets used in elevators may be deep, shallow or V-shaped (Fig. 103*c*, *d*, *e*, respectively). Deep buckets ranging from 1 to 30 litres in capacity are used for conveying dry sand and gravel; shallow ones, from 0.6 to 33.5 litres in capacity are employed for cement and moist sand; V-buckets 1.3 to 130 litres in capacity are preferred for conveying lump materials.

Buckets are made of sheet or cast steel. They are riveted to belts or clamped to chains. Specifications for elevators are listed in Table 13.

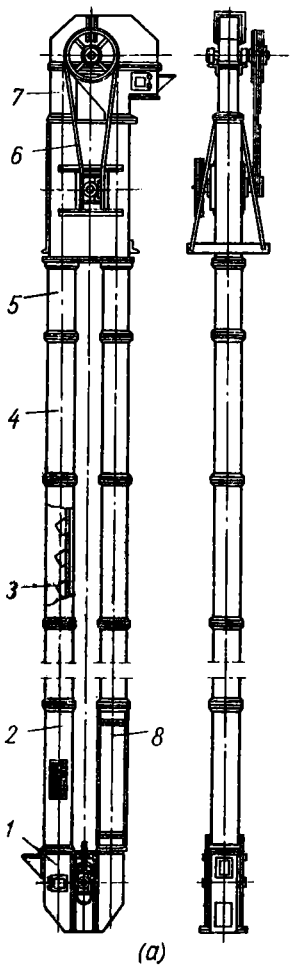
Table 13

Elevator Specifications

Item	Elevator model			
	T-50	T-51	T-52	T-56
Capacity, t/hr	14	15-30	20	40
Speed, m/s	1.2	0.3-0.6	1.25	0.36
Bucket capacity, litres	0.75	3	2	4
Chain pitch (belt width), mm	150	100	100	100
Maximum height of elevation, m	17	10	18	20.4
Slope, deg	90	60	90	60
Motor ratings:				
power, kW	2	2.5	4.5	6
rpm	—	970	950	970
Overall dimensions, mm:				
length	800	5,800	900	—
width	200	1,200	500	900
height	18,000	20,400	19,500	21,000
Weight, kg	1,000	2,440	2,800	7,000

T-50 Belt-and-Bucket Elevator (Fig. 104*a*). This elevator consists of head *7*, drive *6*, boot *1*, belt with buckets *3* and four different types of housing pipes *4*, *2*, *8*, and *5*.

The gear train diagram of the elevator drive (Fig. 104*b*) is as follows: rotation is transmitted from motor *9* by means



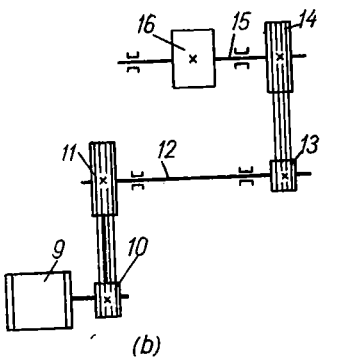


Fig. 104. T-50 belt-and-bucket elevator:

(*a*) construction, (*b*) gear train diagram; *1*—boot, *2*, *4*, *5*, *8*—housing pipes, *3*—buckets, *6*—drive, *7*—head, *9*—motor, *10*, *13*—drive pulleys, *11*, *14*—driven pulleys, *12*, *15*—shafts, *16*—elevator head pulley

of a V-belt drive constituting drive pulley *10*, four V-belts and driven pulley *11*, to an intermediate shaft *12* and thence by means of a similar drive consisting of drive pulley *13*, four V-belts and driven pulley *14*, to the drive shaft *15* and the elevator head pulley *16* seated on it.

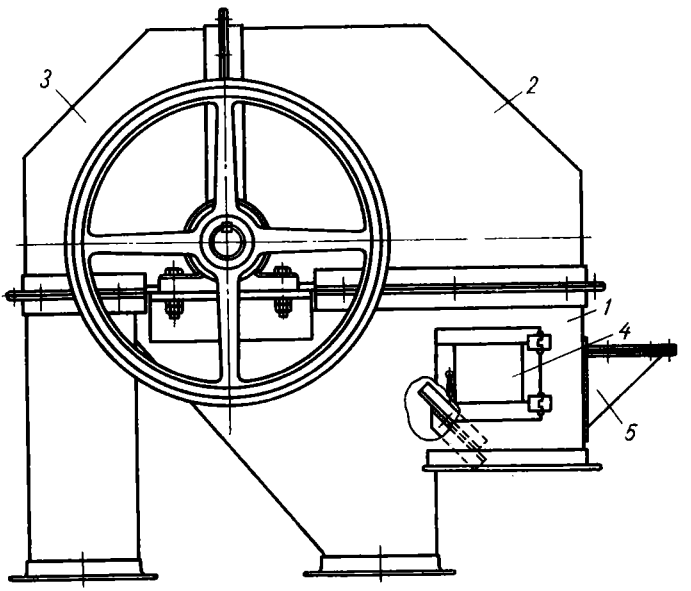


Fig. 105. T-50 elevator head:
1, 2, 3—casing parts, *4*—door, *5*—snout

The elevator *head* (Fig. 105) consists of the drive shaft with the drive belt pulley and the driven gear train pulley seated on it, enclosed in the head casing.

The head casing supports the drive shaft bearings and serves as a guide for directing the loose material discharged by the buckets into the delivery chute. The casing consists of three parts *1*, *2*, and *3*, which are bolted together. Each part is a welded structure made of sheet and angle steel. The bottom part *1* of the casing has a door *4* to enable observation of bucket discharge, and a snout *5* through which the dusty air is exhausted from the elevator casing.

The dust is kept inside the head casing with the help of felt rings inserted in special grooves in the casing.

The elevator head drive shaft *1* (Fig. 106*a*) with the elevator head pulley *2* keyed to it and held in place with stop screws is supported by two ball bearings *4*. The driven V-belt pulley *3* is keyed to the end of the drive shaft.

The intermediate shaft *6* (Fig. 106*b*) is supported by two ball bearings *4*. Keyed to this shaft are pulleys *8* and *9* of the V-belt drive.

Belt take-up is adjusted by means of screws *5*. The bearings of the intermediate shaft are bolted to sliders *7*.

The elevator *boot* (Fig. 107) consists of the tail pulley and the take-up, enclosed in a welded steel casing *1*. The material to be conveyed is fed through snout *3*. Loading of the buckets can be observed through a door *2* made in the side wall of the casing. The casing has a hatch with a gate *4* for removing material. The side walls of the casing have guides *8* welded to them along which the sliders *7* of the take-up move. The sliders *7* are cast-iron plates with brackets to which the take-up shaft bearings *9* are hinged. The sliders are connected to screws *5* fitted with nuts which ride in cross pieces *6*.

The take-up pulley is raised or lowered by rotating the nuts clockwise or counterclockwise, thus reducing or increasing the belt tension. The tail pulley shaft is supported by ball bearings.

The elevator *belt 1* (Fig. 108) is a rubber coated five-ply duck belt. Both the loaded and the return sides of the belt are enclosed in square pipes.

The elevator *buckets 2* are made of sheet steel. Buckets are fastened to the belt *1* with bolts *3*, nuts *4* and concave washers *5*. The bolt heads are flush with the belt surface, and the belt fits into a groove in the back wall of the bucket at the place of fastening. This ensures smooth passage of the bucket fastenings over the pulleys.

The *pipes* (see Fig. 104) are made of sheet steel. They have cast-iron flanges on their ends. The complete set of each elevator includes pipes of four types: pipe *4* of standard height with unbroken walls; pipe *2* with an inspection hatch; pipe *8* with a hatch for connecting the ends of the elevator

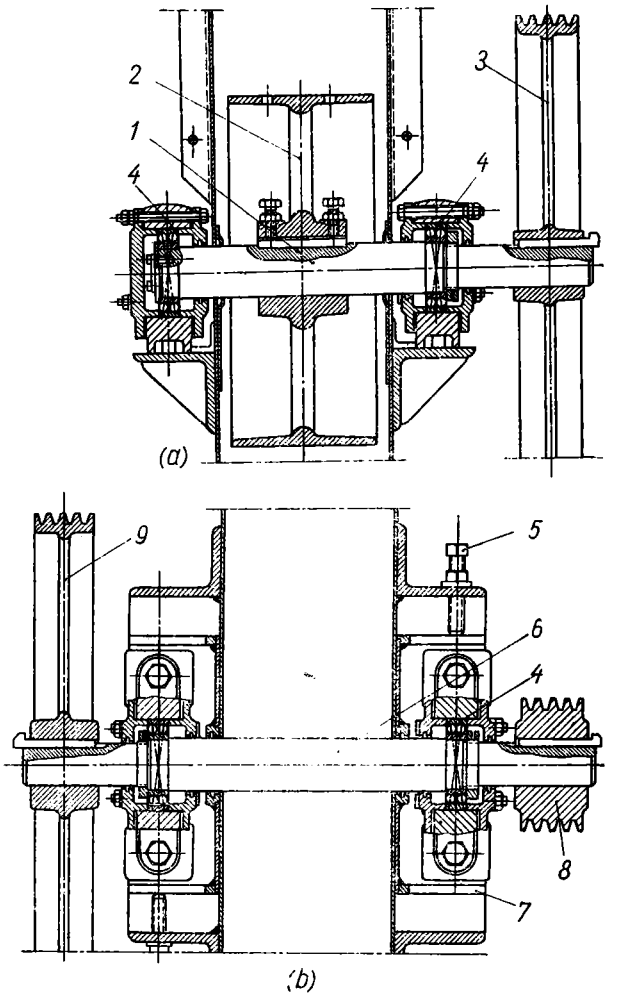


Fig. 106. T-50 elevator drive:

(*a*) drive shaft assembly, (*b*) intermediate shaft assembly; *1*—drive shaft, *2*—elevator head pulley, *3*, *8*, *9*—pulleys, *4*—bearing, *5*—screw, *6*—intermediate shaft, *7*—slider

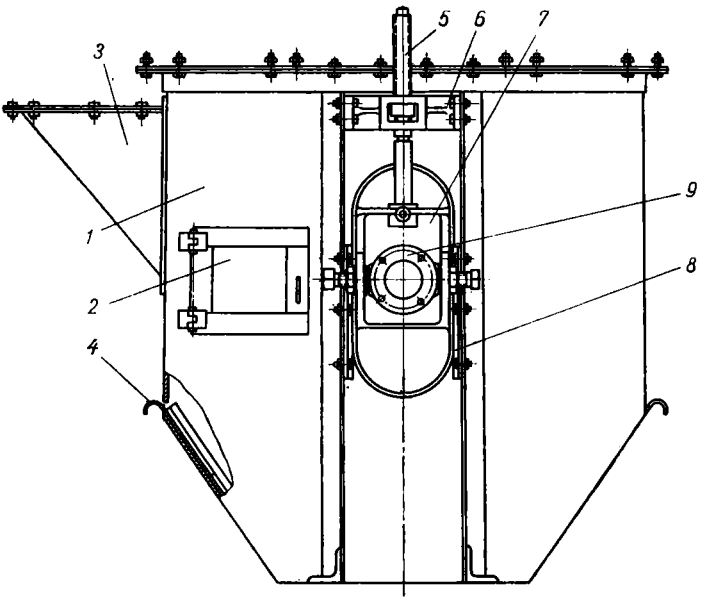


Fig. 107. T-50 elevator boot:
1—casing, *2*—door, *3*—snout, *4*—gate, *5*—screw, *6*—cross piece, *7*—slider, *8*—guide, *9*—bearing

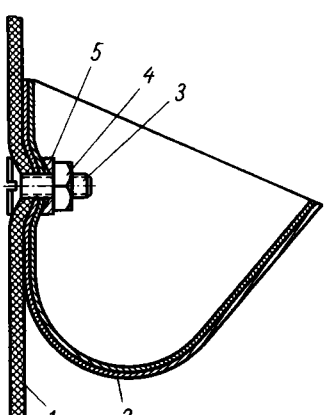


Fig. 108. T-50 elevator belt with bucket:
1—belt, *2*—bucket, *3*—bolts, *4*—nut, *5*—washer

belt during assembly and repairs, and pipe *5*, shortened with unbroken walls.

Installation of T-50 Elevator. Assemble the elevator starting from the boot, setting it on a foundation and bolting it down. Assemble the drive on the roof girders or on a special steel structure, and bolt the head to it without its casing.

Assemble the pipes in the following order. Set the pipe with the inspection hatch on the boot on the feed snout side, and the pipe with the belt take-up hatch, on the opposite side; set the standard-height pipes upon these pipes; shortened pipes may be installed anywhere between the hatched pipes and the drive assembly. The pipes may be assembled on the ground and reinforced with square timber or boards. Then raise the assembled pipes with a winch and put them vertically on the boot. After bolting the pipe flanges to the boot and head remove the timber.

When assembling the elevator make sure that the pulley shaft and drive shaft axes are all in the same vertical plane, that the pipe axes are strictly vertical and that the take-up and drive pulleys are well aligned.

Check pulley alignment by the clearance between the casing wall and the pulley end; these clearances should be equal for both pulleys and should not vary when the pulley is rotated.

Arrange the drive shaft pulleys and the drive (small) pulley of the intermediate shaft in the same plane.

The take-up pulley should be easy to raise and lower using the take-up mechanism, and the shafts should rotate freely when turned by hand.

When bolting the buckets to the belt tighten the nuts as far as they will go and see that the bolt heads are flush.

When the belt and buckets are fully assembled lift them to the elevator head, having first removed the top parts of the casing; let the belt ends down over the head and through the pipes into the boot. Draw one end of the belt (on the loaded side) under the take-up pulley, raise it to the belt take-up hatch and join it to the other end. During this operation the take-up pulley should be in its uppermost position.

The belt ends may be butt joined with special clamps and clips or lap joined by sewing. Align the belt with the pulleys and take up its slack with the take-up mechanism.

Rotate the drive pulley by hand for several revolutions of the belt. Then install the motor and starting equipment and connect them to the current source.

Set the motor on guide rails. Take care that the motor pulley and the large (driven) pulley are in the same plane.

Put the V-belts in place as usual: adjust the slack of both drives—from the motor to the intermediate shaft and from the latter to the head drive shaft—simultaneously by means of the thrust screws.

Test the elevator by starting it with empty buckets. If no defects are revealed thereby gradually load up the elevator.

During the test run check all the parts of the elevator to see whether they are functioning properly.

T-52 Chain-and-Bucket Elevator (Fig. 109*a*). This elevator consists of head *1*, boot *2*, chain *3* with buckets, and steel casings *4* and *5*.

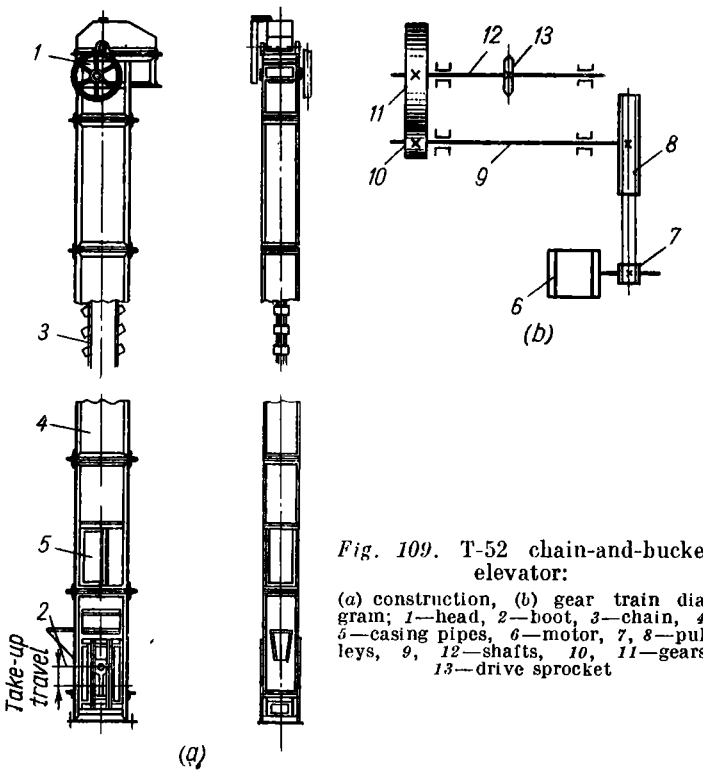


Fig. 109. T-52 chain-and-bucket elevator:
(*a*) construction, (*b*) gear train diagram; *1*—head, *2*—boot, *3*—chain, *4*, *5*—casing pipes, *6*—motor, *7*, *8*—pulleys, *9*, *12*—shafts, *10*, *11*—gears, *13*—drive sprocket

The endless flat-linked haulage chain with buckets bolted to it 300 mm apart runs around top (drive) and bottom (take-up) sprockets.

Fig. 109*b* is the gear train diagram of the elevator. Rotation is transmitted from the electric motor *6* through a belt drive with driving *7* and driven *8* pulleys to an intermediate shaft *9*, and thence through gears *10* and *11*, to the drive shaft *12* and the drive sprocket *13* seated on it.

The elevator *head* (Fig. 110) consists of chain drive shaft *1* with its drive sprocket, intermediate shaft *3* and casing *2*; the head is provided with a removable cap *4* at the top and a door *5* in its lower part.

The head casing directs the material discharged by the buckets into the delivery chute; the lower part of the casing holds the bearings of the intermediate and chain drive shafts.

The chain drive shaft is supported by two ball bearings. The drive sprocket is seated on this shaft. The end of the shaft carries the driven gear rotated by the pinion on the intermediate shaft.

The intermediate shaft *3* is also supported by two ball bearings, the housings of which are mounted on angles welded to the head casing. To one end of this shaft is keyed the driven belt drive pulley, rotated by the belt drive, and to the other, the drive pinion engaging the gear on the drive shaft. To protect the intermediate shaft from falling lumps of the transported material, it is enclosed in a steel pipe.

The *boot* (Fig. 111) consists of the tail sprocket and the take-up enclosed in a welded casing of sheet and angle steel. A feed snout *1* through which the elevator is loaded is bolted to the casing wall *2*.

The casing walls have doors *3* through which the tail sprocket *6* and the chain can be inspected, repaired and greased. The bottom *9* of the casing is rounded and has two hatches for removing spillage. The sprocket *6* rotates on two ball bearings seated on an axle and moves up and down together with slider *5*. A guard *4* protects the sprocket teeth from falling material.

The *take-up* consists of slider *5*, rod *8*, pinned to the latter, and frame *7*.

The take-up frame is bolted to the boot casing. The longitudinal slot of the frame is closed against dust with a shield which moves along the guides together with the axle. The hole in the shield for the sprocket axle to pass through is sealed with a gasket ring.

The slider *5* moves along guide rails fixed to vertical angles on the take-up frame. The end of the rod passes through a thrust strip on the frame, to which it is fastened with nuts on both sides, this fastening making it possible for the rod to move up and down with the slider and sprocket axle.

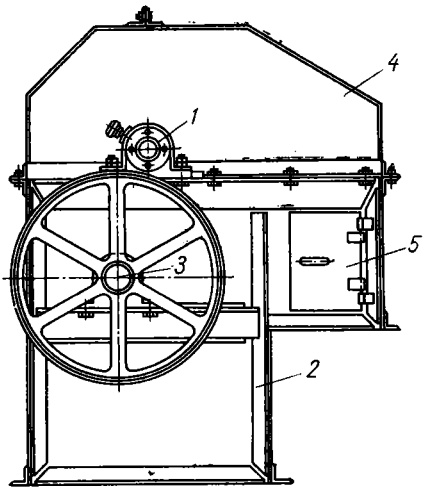


Fig. 110. T-52 elevator head:
1, *3*—shafts, *2*—casing, *4*—cap, *5*—door

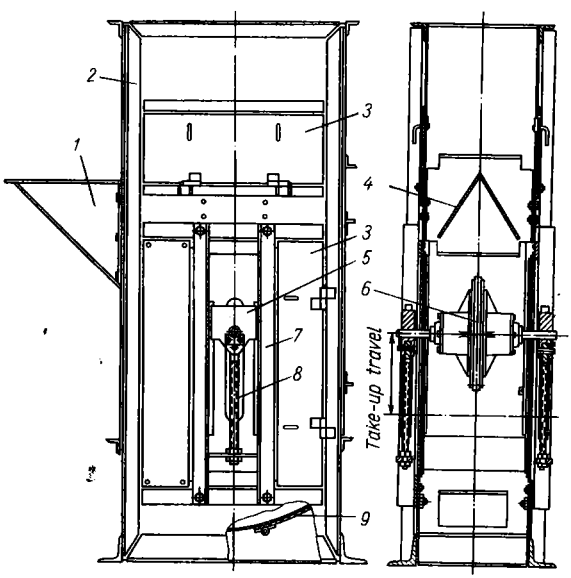


Fig. 111. T-52 elevator boot:
snout, *2*—casing wall, *3*—doors, *4*—guard, *5*—slider, *6*—sprocket, *7*—frame, *8*—rod, *9*—casing bottom

The elevator *chain* (Fig. 112) is a flat-linked stud and roller chain with a pitch of 100 mm. Every third link has fastening plates with outward bent lugs to which the buckets are bolted with four nut bolts each. The buckets 2 litres in capacity are made of sheet steel.

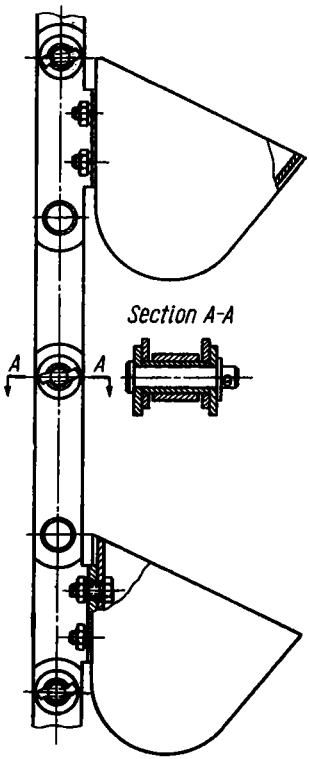


Fig. 112. T-52 elevator chain with buckets

The *casing pipes* (see Fig. 109*a*) are made of welded sheet and angle steel; the pipes are bolted together to form the casing. One of the pipes has a hatch with a door affording access to the elevator for maintenance.

Installation of the T-52 Elevator. Mount the elevator on two supports, the lower being the boot foundation, and the upper, a supporting structure under the head. If the elevator is not more than 6 or 8 m high it may be set up with only a bottom support; in this case the head must be supported with braces.

Start assembling the elevator from the boot, then assemble the head and the chain and buckets.

Assemble the casing after installing the boot.

When assembling the elevator make sure that the axes of the top and bottom sprockets are in the same vertical plane; that the sprockets are well aligned; that the boot casing walls are strictly vertical; that the tail sprocket axle is at right angles to the vertical and longitudinal boot axes; that the sprocket and its axle can be raised and lowered readily using the nuts on the take-up connecting rods; that the take-up shield plate moves freely along its guides, and that the guard protects the sprocket effectively from falling material.

Check the setting of the boot and the head with a plumbline. Arrange the sprockets symmetrically with respect to the casing walls. Check the sprocket setting with a plumbline and by the clearance between the sides of the sprocket teeth and the casing walls. These clearances should be the same on both sides and should not vary when the sprockets are rotated by hand.

Fasten the gear guards to the head casing.

Before installing the chain soak it in hot oil, then lay it out on clean boards and bolt the buckets to the fastening links. Set the buckets with their edges at right angles to the chain axis and tighten the nuts down well.

Lift the assembled chain to the head, set it on the top sprocket (with the head cap removed), then lower both its ends to the tail sprocket, wrap the chain around it and connect the chain ends. Take up the slack of the chain.

Set the first casing pipe on the boot, and then the others one by one on top of it, bolting them together. Include the hatched pipe in any place convenient for maintenance of the elevator: this is most often just above the boot. Use a plumbline when installing the casing.

Install the motor on slide rails. See that the motor pulley and the driven pulley on the intermediate shaft are in the same plane.

After assembly make a test run of the elevator. First start it at no load. Then build up the load gradually. During the test run check the operation of all parts of the elevator and eliminate all defects detected.

T-49 SCREW CONVEYOR

Screw (worm) conveyors are used for conveying free flowing, small-grained and plastic materials (cement, sand, mortar, etc.) horizontally, vertically or along an incline over distances up to 60 m.

The capacity of a screw conveyor may be as high as 100 m^3/hr.

The T-49 screw conveyor (Fig. 113) consists of a box *1*, drive shaft *2* with a conveying screw *3* secured to it, bearings *4*, a feed pipe *5*, discharge hatches *6* with gates, and a drive.

The box is made of sheet steel in sections which can be bolted together. Shafts are made of 4,000-mm lengths of piping joined with couplings. The shaft is set in bearings spaced 2.5 to 3 m apart; the bearings are fastened to the side of the box opposite the direction of movement of the material. The end of the shaft is supported by a thrust bearing. The screw is actuated by an electric motor through a gear drive.

The material is fed into the closed conveyor box through the feed pipe—an opening in the box cover. The material can be discharged at definite points along the length of the box through hatches with gates.

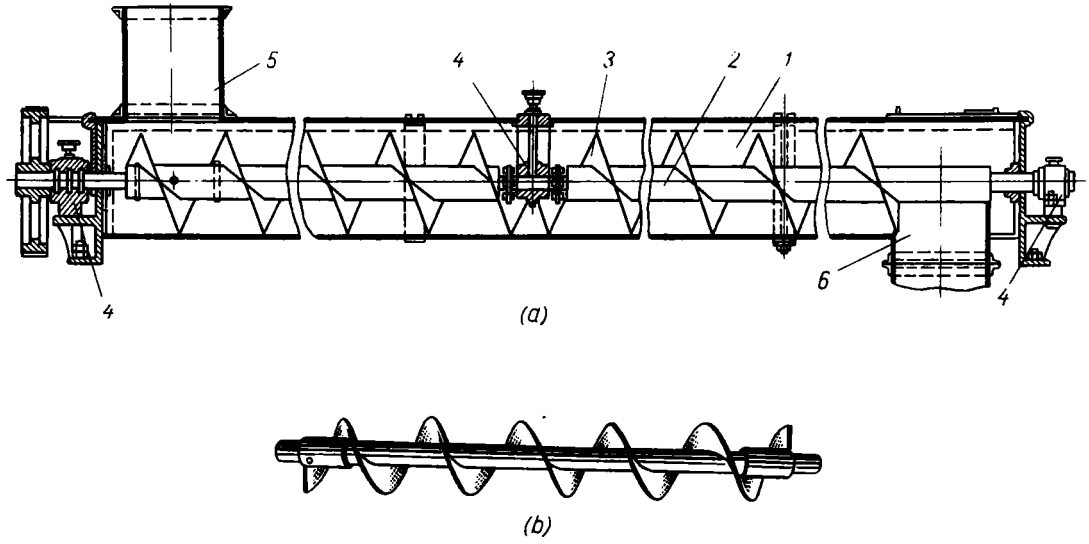


Fig. 113. Screw conveyor:
(*a*) construction, (*b*) conveyor screw; *1*—box, *2*—drive shaft, *3*—screw, *4*—bearing, *5*—feed pipe, *6*—discharge hatch

T-49 Screw Conveyor Specifications

Capacity, m^3/hr	15
Screw dimensions, mm:	
diameter	300
pitch	240
Screw rpm	72
Maximum conveyor length, m	36
Box dimensions, mm:	
width	600
height	650
section length	4,000
Length of shaft section, mm	1,822
Motor power rating, kW	2.7
Weight at maximum length, kg	2,400

25. Crushing Machinery

Crushers (breakers) are employed for comminuting (crushing) large pieces of rock into crushed stone for use in making concrete, in railway and road construction, as well as for crushing slag to make artificial rocks, etc.

The chief performance indices of crushers are their specific capacity expressed in tons or cubic metres per kilowatt-hour of work done and their reduction ratio, this being the ratio between the diameter of the largest lump of feed and the largest lump diameter of the crushed product.

The material charged into the crusher is called the *feed*, and that discharged from the machine after crushing, the *crushed product*. The size of the crushed product varies depending on its purpose.

Crushing is called coarse when the resulting lumps are from 70 to 300 mm in size, intermediate when their size is 20-70 mm and fine when the product size is from 1 to 20 mm; as a result of fine grinding the grains of the product are reduced to fractions of a millimetre.

Ordinarily the lumps of the initial feed are much larger than the size desired in the crushed product, so that it is unpracticable to obtain the required product in a single stage (or step). In such cases crushing is done in several stages (or steps) whereby the lump size of the crushed product is

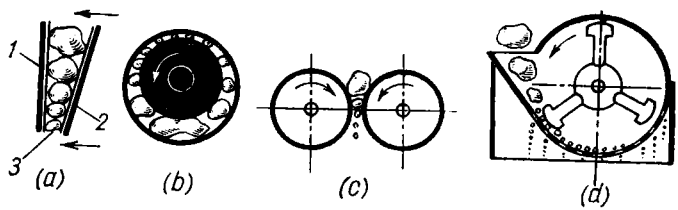


Fig. 114. Schematic representation of comminution methods: (*a*) in jaw breakers, (*b*) in cone crushers, (*c*) in rolls, (*d*) in impact crushers; *1*, *2*—jaws, *3*—discharge opening (set)

reduced gradually from step to step; thus, crushing may be single-stage or multistage.

The lumps of the feed may be comminuted by pressure crushing, splitting, impact or abrasion; these methods may be combined, as pressure and impact, etc.

The best method of comminution for each particular case depends on the physical and mechanical properties of the feed, its lump size and the required size of crushed product.

Coarse and intermediate crushing of hard rocks is most commonly accomplished by pressure; grinding is done by abrasion and impact. The methods of comminution used in various crushing machines are illustrated schematically in Fig. 114.

JAW CRUSHERS

Jaw crushers (also called jaw breakers) are used for coarse and intermediate crushing of medium-hard and hard (strong) rocks. The rock fed to these machines is crushed between two plates (jaws). Comminution takes place as follows: jaw *1* is fixed, while jaw *2* swings to and fro, pressing the stone intermittently against the fixed jaw; when the swing jaw moves away on its back stroke the crushed rock gradually settles in the space between the jaws and is finally discharged as the crushed product through the discharge opening *3*. The wider the discharge opening, the coarser the crushed stone. Hence, these machines crush by pressure.

Jaw crushers may be of the double-toggle or single-toggle type, the former being used mainly for coarse, and the latter, for intermediate crushing.

Specifications of the jaw crushers most commonly used in civil engineering are listed in Table 14.

Table 14

Jaw Crusher Data

Item	Single-toggle				Double-toggle				
	C-182B	CM-11B	CM-166A	CM-16A	C-644	CM-211	CM-204A	900/1,200	1,200/1,500
Capacity, m^3/hr	3.5-14	8.5-22	6-30	35-120	8.15-20.4	22-62	42-110	140-200	250-350
Gape width, mm	20-80	40-100	20-80	75-200	40-100	up to 125	75-200	150-200	200-250
Discharge opening, mm:									
length	400	600	900	900	600	500	600	1,200	1,500
width	250	400	250	600	400	800	900	900	1,200
Drive shaft rpm	300	250	275	250	300	300	275	170	135
Motor power rating, kW	20	28	28	75	28	40	75	110	180
Overall dimensions, mm:									
length	1,330	1,650	1,352	2,250	2,100	3,420	3,750	4,565	6,280
width	1,200	1,720	2,045	2,280	1,720	2,330	2,400	3,784	4,450
height	1,415	1,520	1,230	2,430	1,850	2,150	3,000	2,660	3,840
Weight without motor, kg	2,500	5,650	5,830	15,350	7,500	19,200	26,874	59,080	141,000

C-644 Double-Toggle (Blake-Type) Jaw Crusher (Fig. 115). This crusher consists of the following chief elements: main frame *6*, eccentric shaft *17*, flywheel *7*, pitman *5*, swing jaw

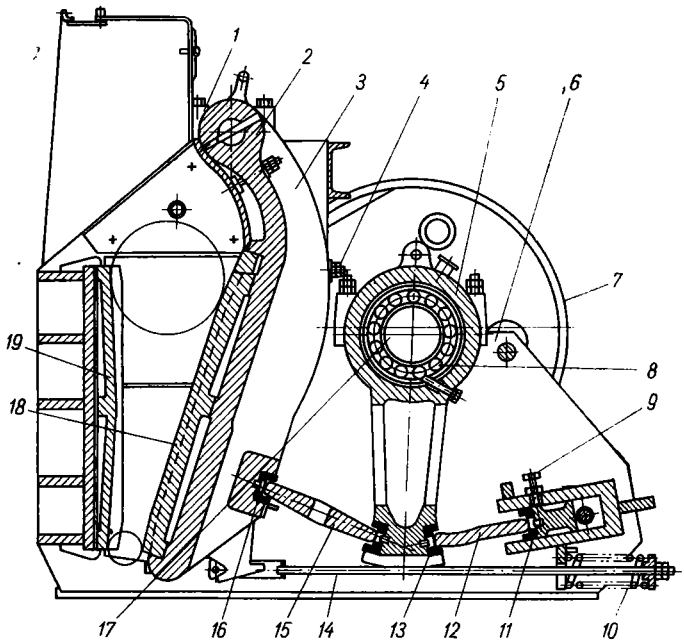


Fig. 115. Double-toggle (Blake-type) jaw crusher:
1, *8*—bearings, *2*—hub, *3*—swing jaw, *4*, *9*—bolts, *5*—pitman, *6*—main frame, *7*—flywheel, *10*—spring, *11*—discharge opening adjustment mechanisms, *12*, *15*—toggles, *13*—toggle seats, *14*—tension rod, *16*—toggle seat, *17*—shaft, *18*, *19*—jaw plates

3, jaw plates *18* and *19*, toggles *12* and *15*, and mechanisms *11* for adjusting discharge opening, with adjusting block.

The *main frame 6* is a steel casting, ribbed for strength and furnished with holes at the bottom for bolting to the foundation.

The *eccentric shaft 17* rests with its necks on bearings *8* supported by the side walls of the main frame. The part of the shaft between the necks is an eccentric. The shaft is a

steel forging. Flywheels *7* are keyed to the shaft ends for smooth operation. A belt drive pulley keyed to one end of the shaft next to the flywheel supplies the rotation transmitted from the motor.

The *pitman 5* has a bearing at its top, seated on the eccentric of main shaft *17*. The bottom of the pitman has recesses on both sides fitted with toggle seats *13* to accommodate the rounded ends of the toggles *12* and *15*. The pitman is a steel casting.

The *swing jaw 3* is suspended by a top hub *2* from the swing jaw shaft on which it swings. The hub is fitted with a bushing which can be replaced when it wears out; the axle is supported by bearings *1*.

The swing jaw hub and bushing have a hole bored through them into which a grease cup is screwed. At its bottom the jaw has a rib with a recess fitted with a toggle seat *16* for the rounded end of toggle *15*.

The swing jaw, toggles and bottom of the pitman are held together with a spring *10* seated on a tension rod *14* hinged to the swing jaw.

The swing jaw is a steel casting and is ribbed for strength.

The *toggles 12* and *15* have rounded machined ends. They are made of cast iron or steel and may be solid or split and riveted together. The toggles are weaker than the swing jaw, the pitman and the shaft; therefore, if very hard (uncrushable) material gets into the crusher, the toggle, which is cheap and easily replaced, or the rivets holding it together, will fail, relieving the strain from the expensive jaw, pitman or shaft.

One *jaw plate 18* is secured to the swing jaw with special bolts *4*.

Another *jaw plate 19* is placed on the fixed jaw, which is essentially the front wall of the frame, and is held in place by lugs on the ends of the plate and the cheek plates protecting the side walls of the crushing chamber from wear.

The jaw plates have corrugated crushing surfaces. They are cast from alloy (manganese) wear-resistant steel and are shaped so that the ridges of plate *18* come opposite the spaces of plate *19*; this facilitates crushing of the stone. When

worn out, jaw plates are replaced with repaired (built up by welding) or new ones.

The discharge setting is adjusted by means of a wedge-shaped block; raising or lowering this block with bolt *9* causes the adjusting block with its toggle seat to shift left or right along guides on the main frame. Shifting the adjusting block to the left decreases the setting, and shifting it to the right increases the setting.

The crusher operates as follows: as the eccentric shaft rotates the pitman seated on the eccentric presses against the bottom end of the swing jaw through the front toggle and makes it reciprocate together with the jaw plate fixed on it. The swing jaw presses intermittently through its jaw plate on the stone caught between the fixed and swing jaw plates and thus crushes it. The crushed stone gravitates out through the discharge aperture.

CM-11A Single-Toggle Jaw Crusher (Fig. 116). Crushers of this type have no pitmans. The swing jaw has bearings at the top, through which it hangs directly on the eccentric part of the drive shaft. The effect is that rotation of the shaft causes the swing jaw not only to move back and forth, but up and down as well, forcing the feed downwards towards the discharge aperture. In the course of this downward movement the lumps roll over and are partly abraded. Due to accelerated movement of the feed towards the discharge such crushers have a higher capacity than double-toggle jaw crushers.

These crushers consist of the following chief elements: main frame *12*, swing jaw *2*, swing jaw plate *3*, fixed jaw plate *10*, toggle *5*, spring *6*, adjusting blocks *7* and *8*, adjusting screw *4*, toggle seat *9*, cheek plates *11* and *13*, eccentric shaft *14*, flywheel *1*, and pulley *15*.

The *main frame* (Fig. 117) is a welded steel plate construction. It has a front, back and side walls reinforced by ribs. The side walls carry the bearings supporting the eccentric shaft.

The *eccentric shaft* (Fig. 118) is made of steel. It rotates in roller bearings *4*; dust is kept out of the bearings by means of labyrinth rings *2*, *3*, *6*, *7*, *10*, and *11*. The bearings have oil catch rings *5* and *9*. The shaft has an eccentric part in its middle, embraced by the swing jaw bearings *8*. Keyed to

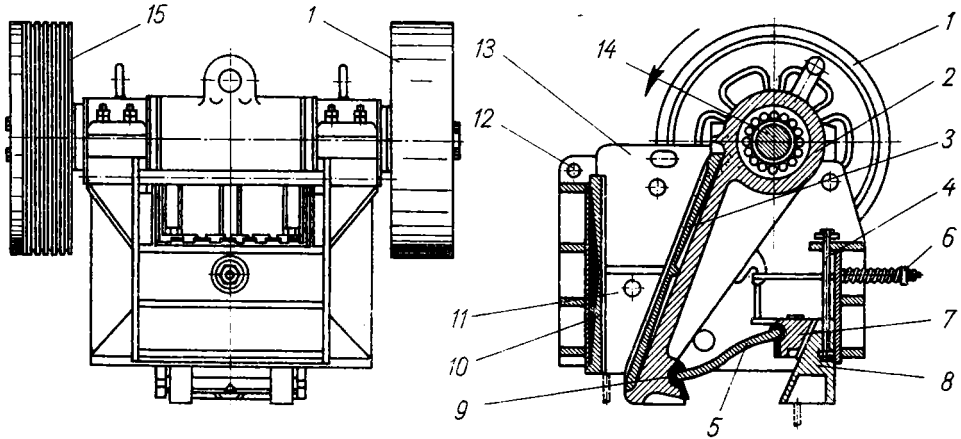


Fig. 116. CM-11A jaw crusher:

1—flywheel, *2*—swing jaw, *3*, *10*—jaw plates, *4*—screw, *5*—toggle, *6*—spring, *7*, *8*—adjusting blocks, *9*—toggle seat, *11*, *13*—cheek plates, *12*—main frame, *14*—shaft, *15*—pulley

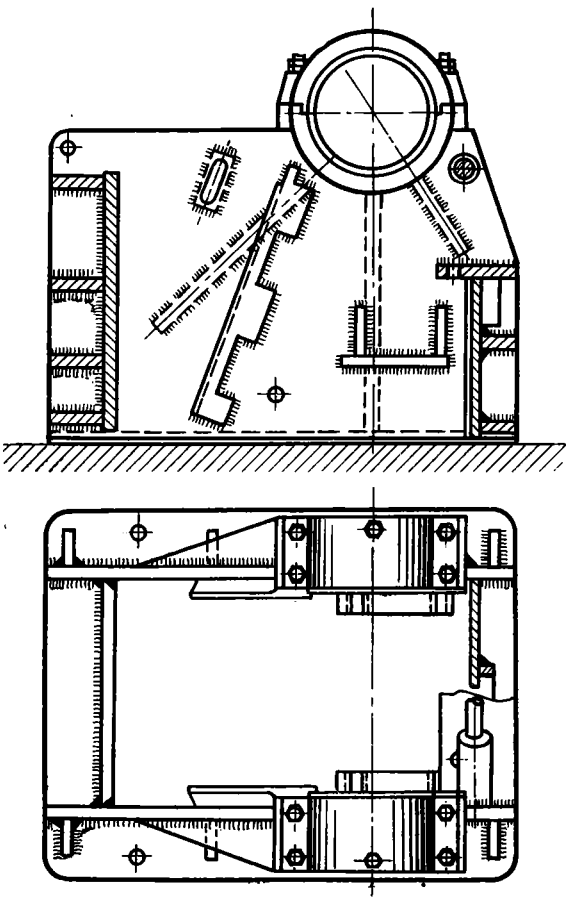


Fig. 117. CM-11A crusher main frame

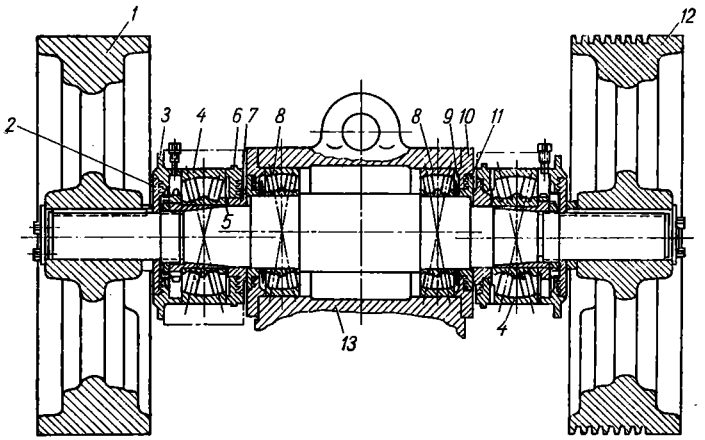


Fig. 118. CM-11A crusher eccentric shaft:
1—flywheel, *2*, *3*, *6*, *7*, *10*, *11*—labyrinth rings, *4*, *8*—bearings, *5*, *9*—rings, *12*—pulley, *13*—swing jaw

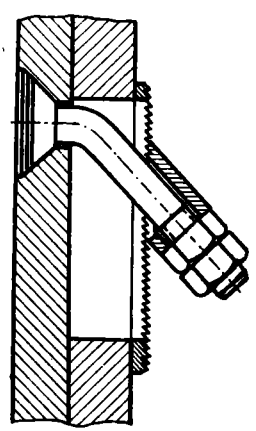


Fig. 119. Bolt for fastening upper cheek plate of CM-11A crusher

the ends of the shaft are flywheel *1* and V-belt pulley *12*, with split hubs bolted together.

The *swing jaw 13* is a ribbed steel casting hung on the eccentric part of the shaft through roller bearings.

The *toggle 5* (see Fig. 116) is arranged between adjusting blocks *7*, *8* and the bottom end of swing jaw *2*, where it rests against the toggle seat *9*. The purpose of the toggle is the same as in the above-described crusher. The swing jaw *2*, toggle *5*, blocks *7* and *8* are held together by spring *6*.

The fixed and swing *jaw plates 10* and *3* have corrugated crushing surfaces; they are cast from wear-resistant manganese steel.

The fixed jaw plate is arranged on the inside of the front frame wall, being wedged between the front wall and a lug (strip) by means of the upper and lower *cheek plates 13* and *11*.

The upper cheek plates of wear-resistant steel are bolted to the side walls of the frame with special bent bolts (Fig. 119). The swing jaw plate is wedged to the swing jaw.

The working zone of the crusher in which the material is crushed is formed by: the front wall of the main frame with the fixed jaw plate, the side walls with the cheek plates and the swing jaw with its plate. Thus, the working zone is bounded all around by wear-resistant surfaces.

The gape width is adjusted (see Fig. 116) with blocks *7* and *8* by means of adjusting screw *4*.

The crusher is actuated by a motor through a V-belt drive with eight V-belts. The drive should rotate the crusher shaft in the direction whereby the upper edge of the flywheel moves downwards towards the feed opening, as indicated by the arrow in Fig. 116.

СМ-11Б Single-Toggle Crusher (Fig. 120). The difference between this crusher and the one just described is in the setting adjustment mechanism.

In the СМ-11Б model the setting is increased or decreased by means of an adjusting screw *1* with right-hand and left-hand threads on its ends; this screw passes through the lug nuts *2* of the adjusting blocks *3*. Rotating the screw shifts the component against which the toggle rests, to left or right, depending on the direction of rotation, and this stretches or compresses the spring, increasing or decreasing the setting.

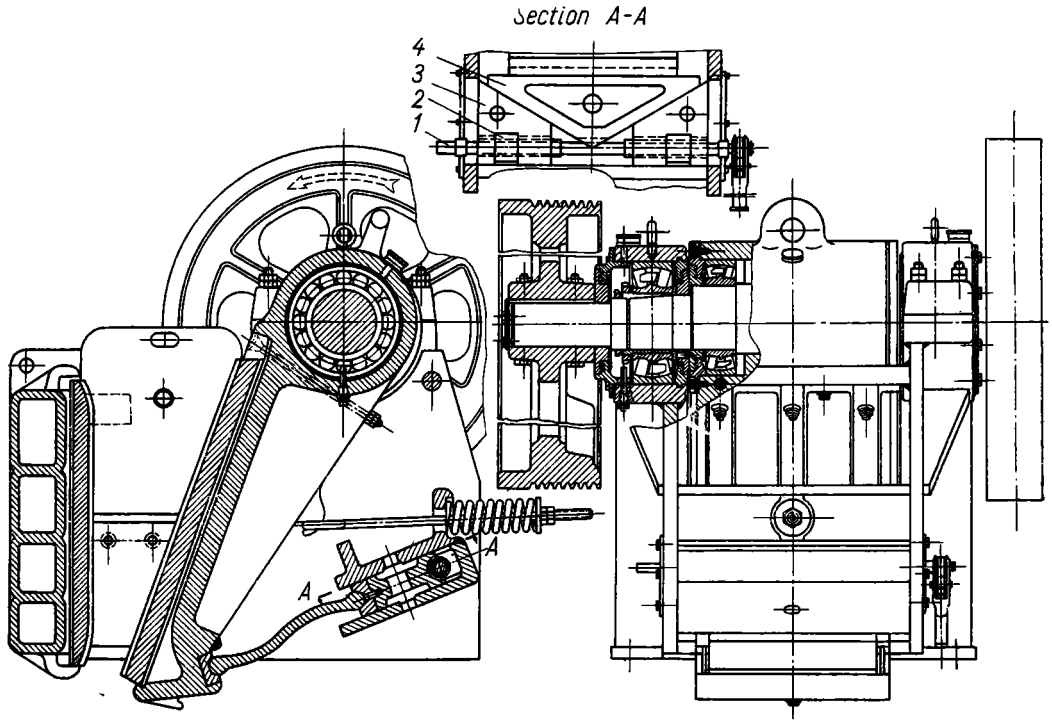


Fig. 120. СМ-11Б crusher:
1—screw, *2*—lug nuts, *3*—adjusting blocks, *4*—component

Installation of Jaw Crushers. Small- and medium-sized crushers are delivered completely assembled. Set the machine on a concrete foundation or on a square-sawn timber frame. To reduce vibration during crusher operation place wooden pillows between its main frame and the concrete foundation. Check the position of the main frame and the eccentric shaft with a level.

Install the motor so as to keep the drive belt trained. Align the motor with the aid of a stretched cord and set square.

When flat belts are used the distance between the motor and crusher drive shaft axes should be not less than three times the diameter of the larger pulley. The lower side of the belt should always be the tight side.

The direction of rotation of the crusher flywheels should be that shown by the arrows on the flywheels.

Before starting the crusher check the fastenings of the jaw plates and other parts and see that the bearing lubrication channels and grooves are clean; fill the grease cups with grease and squeeze it through these channels.

Install a steel pan 1.5 m long at a slope of 15 to 25° for feeding the rock to the crusher.

After the machine and motor have been put in place connect the latter to the current source and test the crusher first under no load and then under load.

CONE CRUSHERS

Cone crushers serve the same purpose as jaw crushers, but unlike the latter they give a reduction ratio of from 10 to 20.

In cone crushers the feed is crushed between two frustums of cones, one of which, called the crushing head, gyrates inside the other, fixed, cone, which is known as the bowl. As the inner cone gyrates, its outer surface alternately approaches and recedes from the inner surface of the bowl. The stone fed into the space between the conical surfaces is crushed due to the pressure built up when they approach each other.

Specifications of cone crushers are listed in Table 15.

CM-560 Standard Cone Crusher (Fig. 121). The main elements of the crusher are: steel shell *11*, rim *19*, adjustment ring *5*, springs *7*, socket *9*, crushing head *20*, eccentric *12*, countershaft *18*, feed superstructure *1*.

The crusher *shell 11* is furnished with a rectangular flange at the bottom for bolting it to the foundation, and a round flange at the top for connecting the rim to it. Within the

Table 15

Specifications of Standard Cone Crushers

Item	Model	
	CM-560	CM-561
Diameter of crushing head base, mm	900	600
Gyrations of head per minute	325	350
Gape, mm	115	75
Setting, mm	15-50	12-25
Capacity at 15-mm setting, t/hr	70	30
Motor power rating, kW	55	28
Overall dimensions, mm:		
length	2,790	1,570
width	1,840	1,200
height	1,950	1,350
Weight, without electrical equipment, lubricating system and pulleys, kg	9,790	3,706
Weight of electrical equipment, kg	1,182	1,182
Crusher control	Semiautomatic from control desk	
Lubrication	Circulation system	

shell is a central cylindrical casting or hub which supports the socket and the eccentric, and a side casting through which the countershaft passes.

The *rim 19* is held against the upper shell flange by helical springs and is threaded into the adjustment ring which supports the conical bowl liner *4*. The crushing head *20* is a hollow steel casting *6* covered with a mantle *3*. The steel casting is pressed on to vertical shaft *13* and rests on a hemispherical bearing *8*. The lower end of shaft *13* is bushed into the inclined tapered bore of eccentric *12*; the eccentric is supported by thrust bearing *16* and is encased in the central steel casting of the crusher shell.

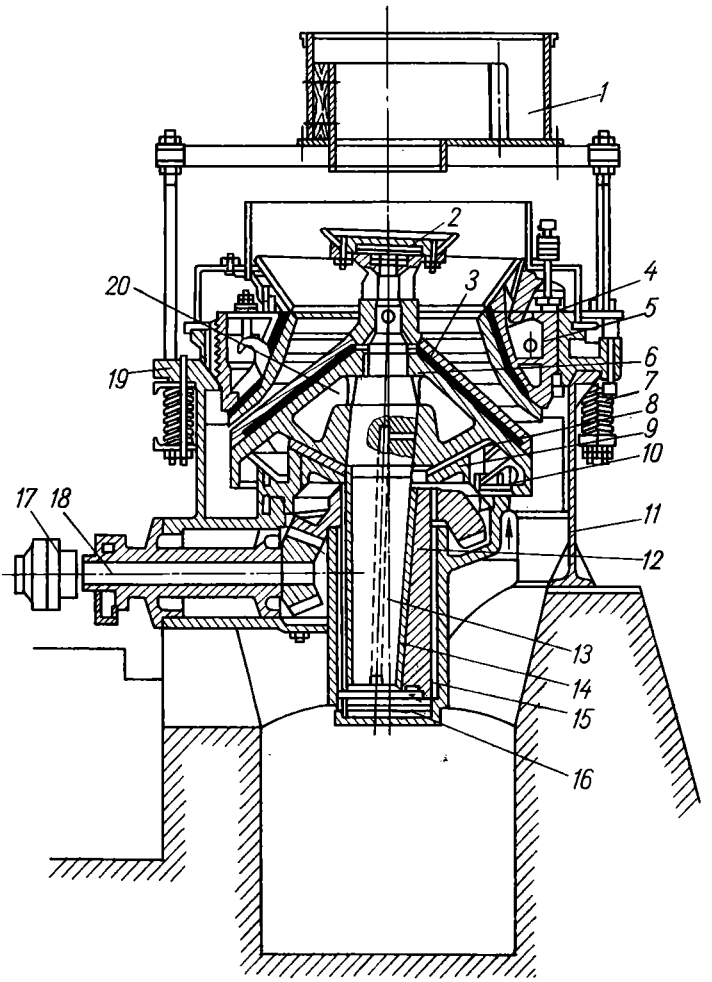


Fig. 121. Standard cone crusher:

1—feed superstructure, *2*—feed plate, *3*—mantle, *4*—bowl liner, *5*—adjustment ring, *6*—crushing head body, *7*—springs, *8*—hemispherical bearing, *9*—socket, *10*—seals, *11*—shell, *12*—eccentric, *13*—vertical shaft, *14*, *15*—bushings, *16*—thrust bearing, *17*—coupling, *18*—countershaft, *19*—rim, *20*—crushing head

The *countershaft 18* is coupled to the motor shaft by means of a flexible coupling *17*, and transmits rotation to the eccentric through the medium of a bevel gear drive.

The *springs 7* holding the rim against the upper shell flange protect the crusher from breakage due to excessive load: if an uncrushable lump of greater than permissible size falls into the crusher, it compresses the springs, allowing the rim, and with it the bowl, to rise, so that the uncrushable lump either passes freely through to the discharge opening or keeps the springs compressed until the crusher is stopped and the lump extracted.

The thread joining the rim and the adjustment ring serves for changing the crusher setting.

The material to be crushed is loaded by a feeder into the superstructure *1* which directs it on to a feed plate *2*.

The crusher has a circulating lubrication system including: an oil sump, a filter-cooler, an electric heater and control instruments. Dust is kept out of the lubricant by means of seals *10* on the socket and on the crushing head. The countershaft bearings *18* have labyrinth and felt seals in their covers to protect them from dust.

The packing ring (dust collar) must not be contaminated.

After 150 hours of operation the upper part of the crusher should be removed, the crushing head lifted out and the collar channels cleaned out.

The eccentric sleeves should fit tightly on the shaft and should be held in place by retainers.

The crushing surfaces should be replaced after they are worn to 50 per cent of their original thickness. The hemispherical bearing should be scraped in to fit the supporting surface.

The edges of the lubricating groove should be sharp to facilitate removal of excess oil.

The threading on the shell for adjusting the width of the crushing zone must be well greased and protected from dust.

CM-561 Cone Crusher. The CM-561 model is of the same design as the CM-560. The difference is that the CM-561 is used for crushing rocks of 75-mm size, while the CM-560 crushes lumps up to 115 mm. Accordingly, its dimensions are smaller and its motor less powerful.

Crusher Operation. *Before starting*:

start up the oil pump motor by pressing the "Start" button on the control desk; this will cause the middle green lamp to flash on at the desk. When oil appears in the drainage pipe the extreme right-hand green lamp will flash on; this is a signal that the crusher motor may be started, which is done by depressing the button on the column marked "Crusher".

During operation:

never start the motor with material in the crushing zone;

stop the crusher and oil pump motors if the oil pressure in the oil lines begins to rise sharply;

do not overload the crusher feed opening; keep the crusher uniformly loaded;

look after the condition of the fastenings, bearings and mechanisms of the crusher;

take care that the belt does not slip.

After work:

before stopping the crusher cut off the feed; switch off the motor only after the crushing zone is free from material;

clean and inspect the crusher and eliminate any defects observed.

Keep the oil sump 3/4 full of oil. Clean the oil screen and strainer once a week; to do so wash them in gasoline or kerosene and then blow them with compressed air. Replace oil after about 1,000 hours of work.

When assembling the crusher and oil lines take care that all friction surfaces and oil lines are clean.

The oil temperature should not be more than 20 or 30° above the ambient temperature.

Check the oil pressure by the pressure gauge.

Installation of Cone Crushers. The crusher is delivered completely assembled and should be set on a reinforced concrete foundation.

When installing the crusher on its foundation it is good practice to place 60- or 70-mm boards under its base.

After installation check the crusher for cocking. It is advisable to install the oil sump with the oil pump and the control box in a dust-protected room.

See that the oil piping is reliably coupled; to avoid leakage use red lead when making the joints.

ROLLS

Rolls are used for intermediate and fine crushing of medium-hard rocks.

Rolls are continuous-pressure type machines in which the crushing is done between two cylindrical rolls rotating in opposite directions. The bearings of one or both of the rolls are made movable to avoid injury to the machine if uncrushable objects of larger than the permissible size fall into the space between the rolls.

Specifications of rolls are given in Table 16.

Table 16

Rolls Specifications

Item	Model	
	СМ-12	ДВГ-2М
Roll dimensions, mm:		
diameter	600	400
face width	400	250
Motor power rating, kW	20	4.5
Roll rpm	75	200
Overall dimensions, mm:		
length	2,235	1,800
width	1,720	1,686
height	810	900
Capacity, t/hr	40	20
Weight, kg	3,330	2,120

CM-12 Rolls. The construction of the crusher is illustrated in Fig. 122. The rolls consist of the following chief elements: main frame *7*, fixed roll *2*, movable roll *5*, feed hopper *4*, drive *1*, housing *9*, *17*, roll shells *3*, *6*, adjustment shims *13*, bearing housing *12*, stop *14*, spring *11*, safety ring *10*, pulley *8*, gears *16*, drive shaft *18*, fixed roll shaft *15*. The movable roll bearings shift under the action of spring *11*. The distance between the roll faces, or the setting, is determined by the position of the stop *14*. Replaceable shells *3* and

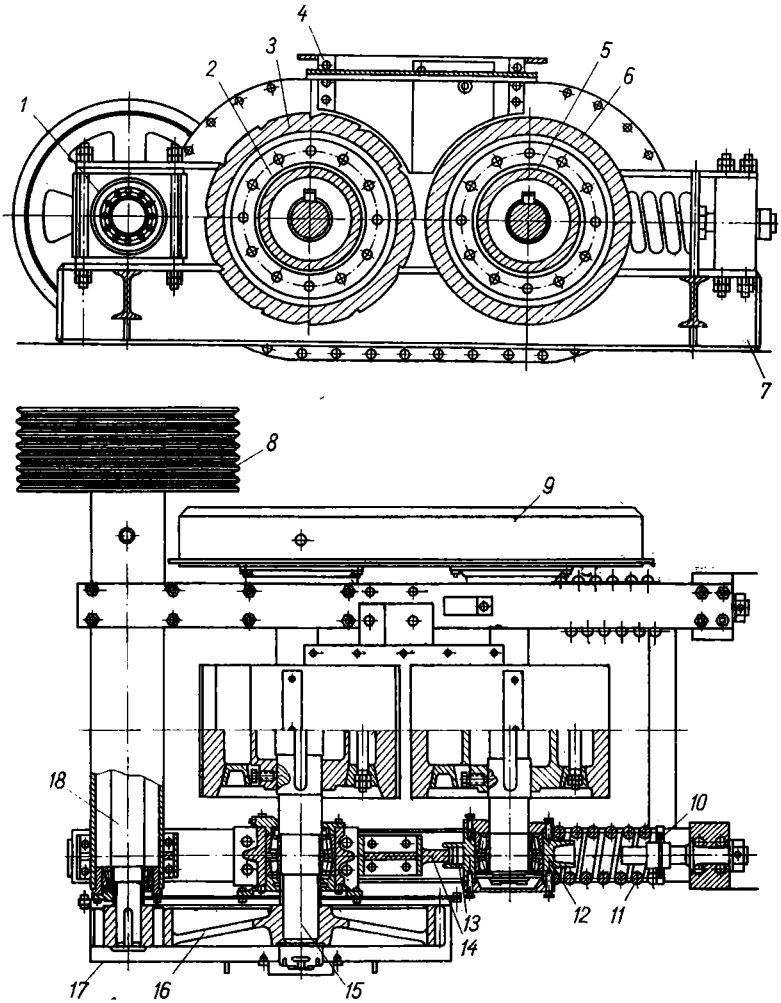


Fig. 122. CM-12 rolls:

1—drive, *2*, *5*—rolls, *3*, *6*— roll shells, *4*—feed hopper, *7*—main frame, *8*—pulley, *9*, *17*—housing, *10* — safety ring, *11*—spring, *12*—bearing housing, *13*—adjustment shims, *14*—stop, *15*, *18*—shafts, *16*—gears

6 of wear-resistant manganese steel form the outer crushing surface of the rolls. The shells may have a corrugated working surface for crushing larger stones.

ДВГ-2М Roll Crusher. This crusher is also intended for intermediate crushing of dry materials and medium-hard rocks. The crusher has smooth faced cylindrical rolls rotating in opposite directions. It operates efficiently with the rolls set at 2 mm or more.

Motors are set on a common frame with the rolls.

The crusher has two rolls, one of which rotates in movable bearings, and the other in fixed bearings. The latter roll can be shifted laterally. Each roll consists of a shell, fixed and movable hearts, and shaft.

The crusher is fed through the housing throat. Inside the throat are two plates for retarding the fall of the feed and directing it on to the crushing surfaces of the rolls.

Operation of Rolls. *Before starting*:

inspect and clean out the feed hopper, check the bearing housing and cover fastenings, the fastenings of the movable hearts holding the shells in place on the rolls, spring tension of the movable roll, and see that the feed hopper liner plates are in place.

During operation:

keep the machine under constant load, taking care not to overload the feed hopper;

keep an eye on the bearings to see they do not get overheated;

make sure all parts of the machine are functioning properly;

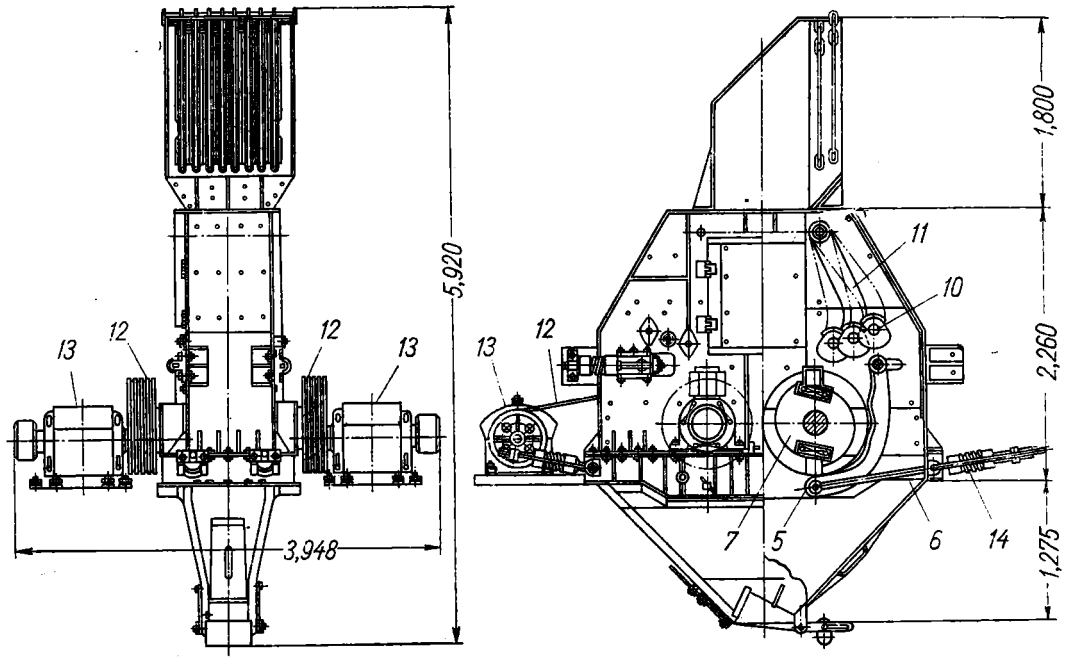
remove deflector angle when crushing brittle material;

keep the crusher well lubricated; keep an eye on the fastenings, bearings and crusher mechanisms.

Installation of Rolls. Rolls are installed on reinforced concrete foundations, observing the same assembly rules as with other types of crushing machines.

ROTOR-TYPE IMPACT CRUSHERS

Impact crushers are used for crushing soft and medium-hard rocks, and limestone irrespective of its hardness. These machines can combine the first and second stages of crush-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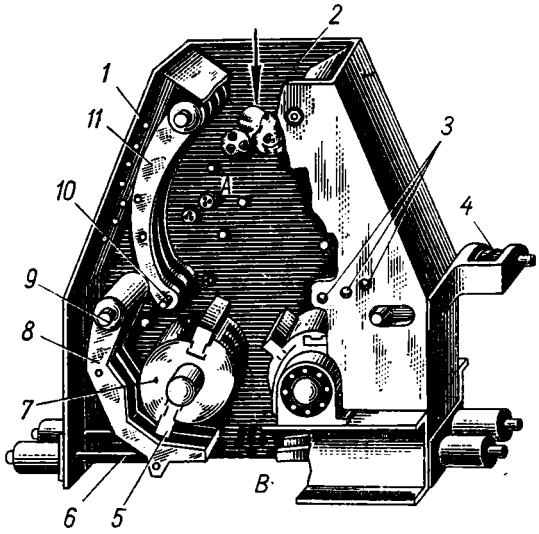


Fig. 123. Impact crusher:

1—housing, *2*—feed entry, *3*—holes for adjusting grates, *4*, *14*—springs, *5*—hammer, *6*—tension rod, *7*—rotor, *8*, *11*—grates, *9*—axle, *10*—bolt, *12*—V-belt drive, *13*—motors

ing into one, and therefore their use simplifies the crushing plant layout.

See Table 17 for technical data on rotor-type crushers.

Table 17

Specifications of Impact Rotor-Type Crushers

Item	Model	
	CM-429	CM-559
Capacity, t/hr	100-200	200-400
Width of feed opening, mm	750	1,250
Maximum lump size of feed, mm	650	1,000
Peripheral speed of hammers, m/s	20-30-40	20-30-40
Number of two-hammer rotors	2	2
Rotor rpm	390-585-780	313-470-625
Width of adjustable grate apertures, mm	55-75-100	70-95-150-200
Range of adjustability of clearance between circumference of rotation of hammers and grates, mm	10-100	70-200
Motors:		
type	AK-91-6	AK-92-6
quantity	2	2
power rating, kW	55	75
Shaft rpm	970	970
Weight (without motors), kg	19,510	64,500
Overall dimensions, including feed and discharge hoppers, mm:		
height	4,822	6,960
width	1,808	3,765
length	4,965	6,110

CM-429 Rotor-Type Crusher (Fig. 123). The crusher has the following construction.

Two massive rotors *7* with two hammers *5* each are arranged on roller bearings in the crusher housing *1*. The rotors are actuated in opposite directions by two electric motors *13* through the agency of a V-belt drive *12*.

Two bottom grates *8* are suspended in the crusher housing on axle *9*, and two upper ones *11*, on bolt *10*.

The position of the bottom grates can be adjusted by means of tension rods *6*; the position of the upper ones can be changed by inserting the retaining bolt in different holes *3*.

To avoid breakage of the bottom grates in case uncrushable material of larger than permissible size comes in between them and the rotor, the suspension axle holes in the housing are elongated, and the ends of the axle rest on springs *4*; for the same reason the tension rods also rest against springs *14* nested in frames. As a result, when uncrushable large-size material comes between the rotor and the grate, the bottom grate drops away and the material is discharged.

Crushing in the machines just described takes place as follows: the lump material fed through feed entry *2* of the crusher falls into space *A* of the housing where it is struck by the hammers and broken, the fragments being thrown back against the upper grate where they are further crushed. Fragments of the desired size are thrown out of the crushing space through the grate apertures, while oversize fragments are again exposed to the blows of the hammers, and part of them fall on the bottom grate where they are additionally crushed in space *B*.

CM-559 Rotor-Type Crusher. This crusher has twice the capacity of the CM-429 model, and the maximum lump size in the feed is 50 per cent larger. Its rotor rpm is 20 per cent lower. The setting range for the rotor-grate clearance is larger, varying from 70 to 200 mm.

HAMMER MILLS

In hammer mills the stone is crushed by means of impact members, these being hammers hung on a swiftly rotating shaft.

Table 18 presents technical data on these crushers.

C-218 Hammer Mill (Fig. 124*a*). This machine is intended for crushing brick, slag, dry clay and limestone. It consists of the following main parts (Fig. 124*b*): housing, rotor *13* and grate *1*.

The feed is admitted in lumps up to 100 mm in size through the entry *10* from which it slides down an incline into the

Specifications of Hammer Mills

Item	Model			
	C-218	CM-18	CM-19A	CM-170
Capacity, t/hr	17-21	6-10	34-54	150-200
Rotor dimensions, mm:				
diameter	600	800	1,000	1,300
length	450	400	800	1,600
Rotor rpm	1,250	950-1,300	1,000	735
Lump size of feed, mm	100	up to 100	up to 300	up to 400
Size of crushed material discharged, mm	35	down to 13	down to 45	down to 10
Motor power rating, kW	14	27-47	115	200
Overall dimensions, mm:				
length	1,050	1,350	2,230	2,600
height	1,029	1,000	1,515	1,900
width	1,122	1,180	3,530	2,740
Weight, kg	1,280	2,000	5,050	10,250

crushing chamber. Here the lumps are broken by blows of the hammers, and are thrown back against corrugated plates *12*. This impact crushes them further and throws them back to the hammers or on to the grate. The crushed product falls out of the chamber through the grate apertures into a bin or a means of conveyance.

The *housing* is of cast iron and consists of base *3* and cover *6* secured with bolts *4*.

The inside of the crushing chamber is lined with breaker plates *12* made of manganese steel. The broken lumps thrown against these plates under the blows of the hammers are crushed additionally. Armour plates *7*, *8*, and *11* are made of chilled iron.

The feed entry *10* has an incline of 40°.

Inside the entry is a hinged gate *9* which keeps the pieces of crushed material from flying back out of the crusher. The housing has two doors *14* in its walls for access to the grate.

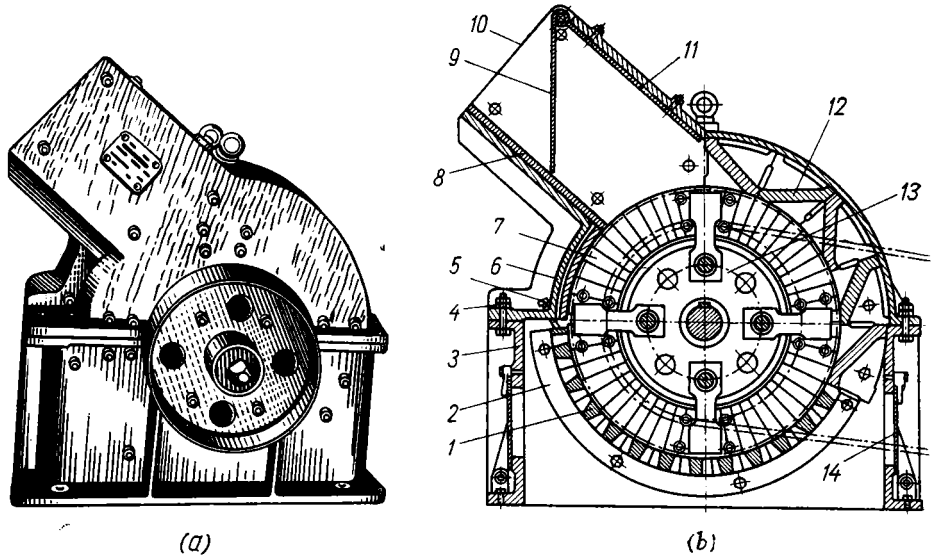


Fig. 124. C-218 hammer mill:

(*a*) general view, (*b*) construction; *1*—grate, *2*—supporting arcs, *3*—base, *4*—bolt, *5*—screw, *6*—cover, *7*, *8*, *11*—armour plates, *9*—hinged gate, *10*—feed entry, *12*—breaker plate, *13*—rotor, *14*—door

The *rotor* (Fig. 125) consists of three disks *3* keyed to a shaft *6* with a prismatic key. The disks are separated by spacing bushings *5* and have two rows of round holes spaced equally around two concentric circles. The first row is

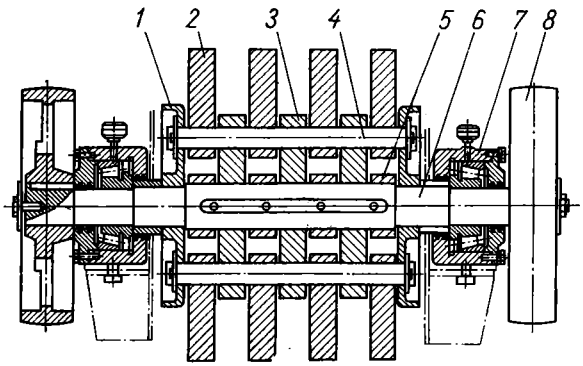


Fig. 125. C-218 hammer mill rotor:
1, *3*—disks, *2*—hammers, *4*—pins, *5*—bushings, *6*—shaft, *7*—bearings, *8*—pulleys

260 mm, and the second, 280 mm away from the centre. Four pins *4* are passed through the holes of one row and splinted on the ends to the disks *1* seated on the rotor shaft. Hammers *2* are hung on pins *4* in the spaces between the disks, four to each pin, so that the total number of hammers is 16. The hammers are wear-resistant steel castings.

The shaft rests on two roller bearings *7* and has pulleys *8* keyed on its ends. One of these is the drive pulley, while the other serves as a flywheel.

When a new set of hammers is installed their pins are passed through the holes closer to the centre. After the hammers are worn short the pins are transferred to the holes farther from the centre. This keeps the clearance between the breaker plates *12* (see Fig. 124*b*) and the hammers, and between the hammers and the grate close to its rated value.

If it is desired to crush to a smaller size, it is necessary to reduce the clearance between the hammers and breaker plates by removing the hammer pins to the holes farther

away from the centre. When one side of the hammers is worn out they should be removed from their pins and turned 180°.

Rearrangement of the hammers must not disturb the rotor balance and therefore before each rearrangement the hammers should be weighed and arranged so that the weight of each row (4 hammers) equals that of the opposite row; the difference in weight should not exceed 30 or 40 g.

The *grate 1* (see Fig. 124*b*) is a set of wedge-shaped bars cast from manganese steel and separated with spacers. The ends of the bars rest on two supporting arcs *2* and are held down by the armour plates *7*. At the end of the grate the bars rest against the breaking plate *12*, being held in place by means of screws *5* which keep them from shifting and vibrating during operation.

The spacing of the bars may be adjusted by replacing the spacers or by using bars of a different size.

CM-18 Hammer Mill (Fig. 126*a*). This mill serves the same purposes as the C-218 model. It consists of three main parts (Fig. 126*b*): housing *7*, rotor *8* with hammers, and grate.

The feed material is crushed in the same way as in the C-218 mill.

The *housing 7* is of welded box-shaped construction consisting of base *1* and cover *2* which are bolted together. The rear wall *3* of the cover can be thrown back on hinge *6* for access to the rotor and hammers which can be replaced without dismantling the housing.

The front and back housing walls have doors *5* affording access to the grates for inspection and replacement. The bolted connection of the housing, doors and hinged cover are furnished with sealing gaskets to keep the dust in.

The material is fed to the mill through an opening *4* in the top housing wall. The housing walls are protected from wear by means of armour plates *9*, *10*, *11*, *12*, *13*, *14*, and *15*. Plates *11*, *12*, *13*, and *14* are stepped; the fragments thrown off by the blows of the hammers are further crushed by impact against these plates. The rest of the plates conceal the housing walls.

The lower part of the housing, the base, is set on a foundation and bolted to it.

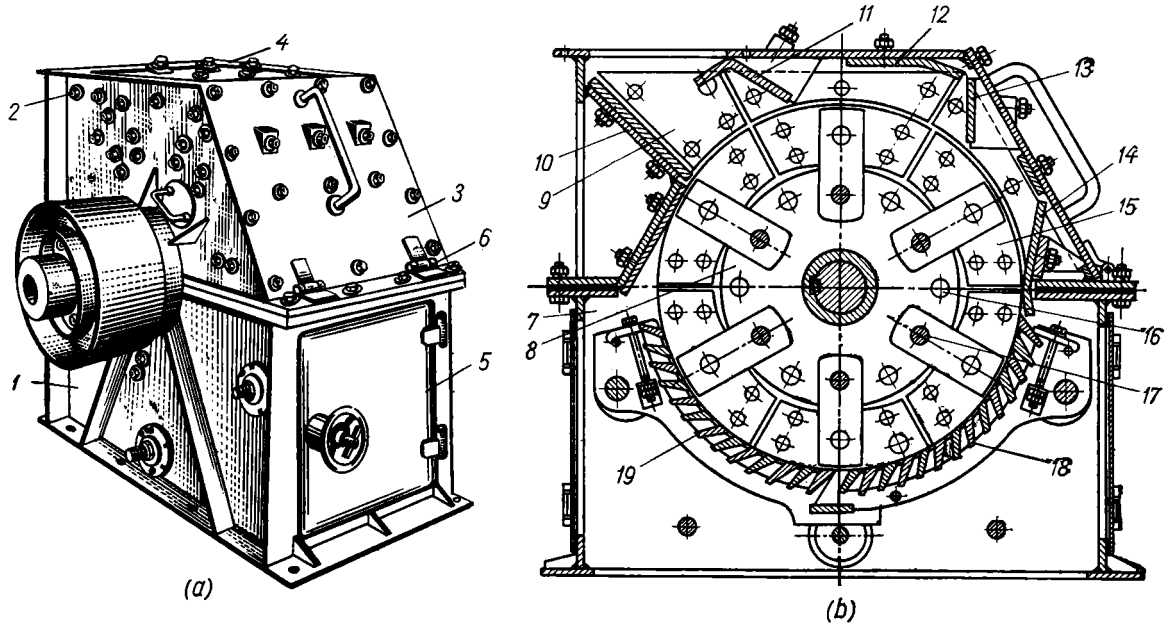


Fig. 126. CM-18 hammer mill:

(*a*) general view, (*b*) construction; *1*—base, *2*—cover, *3*—rear wall, *4*—feed opening, *5*—door, *6*—hinge, *7*—housing, *8*—rotor, *9*, *10*, *15*—armour plates, *11*, *12*, *13*, *14*—breaker plates, *16*, *17*—holes, *18*, *19*—grate bars

The *rotor* (Fig. 127) is a shaft *7* with seven disks *9* keyed to it, on which the hammers *8* are hung. The disks are separated by spacers *13*, keyed to the shaft (prismatic key *6*) and held in place by nut *10*. The disks have two rows of round holes, six to each row, spaced as in the C-218 model. Holes *17* (see Fig. 126*b*) are bored 210 mm, and holes *16*, 225 mm from the centre. Pins *14* (Fig. 127) are passed through holes *17* with twelve hammers *8* swinging from each pin. The pins are made fast by means of cross bars *4* on their ends. When the hammers get worn the pins are removed to holes *16* (see Fig. 126) which are farther from the centre. This keeps the clearance between the hammers and the grate close to its rated value.

Rotor shaft *7* (Fig. 127) rests on two roller bearings *5* and *11*, the housings of which are set on the side walls of the mill housing. Bearing *11* is simultaneously a thrust bearing, i.e., takes axial loads. Bearing *5* should not take axial loads, and for this reason has a clearance between its cover and outer ring. A coupling *12* is keyed to the end of the rotor shaft for connecting the rotor to the motor shaft. This coupling may also serve as a belt drive pulley.

The *grate* consists of a front part *18* and a rear part *19* (see Fig. 126), each being a set of wedge-shaped bars *1* (Fig. 128). The ends of the bars are fixed in two arc-shaped supports *2* connected by stay rods *3*.

The grate is put together bar by bar; their ends are inserted in groove *4* of the arc supports, bar spacing being maintained by means of distance pieces *5* inserted in a T-groove. The last upper bar is held down by a strap *6* tightened by bolt *7* holding the entire set of bars in place and preventing them from shifting or vibrating during operation.

To adjust the grate loosen nuts *1* (see Fig. 127) on the ends of rods *2* against which the grates rest. Then unscrew set screws *3* and using a special wrench turn eccentric rings *15* in the required direction (on both sides of the mill simultaneously); this brings the grate closer or moves it away from the rotor (as shown schematically in Fig. 129), i.e., adjusts the clearance. After setting the grate in the desired position retighten set screws *3* (see Fig. 127) and nuts *1* to fix the eccentric rings *15* in place.

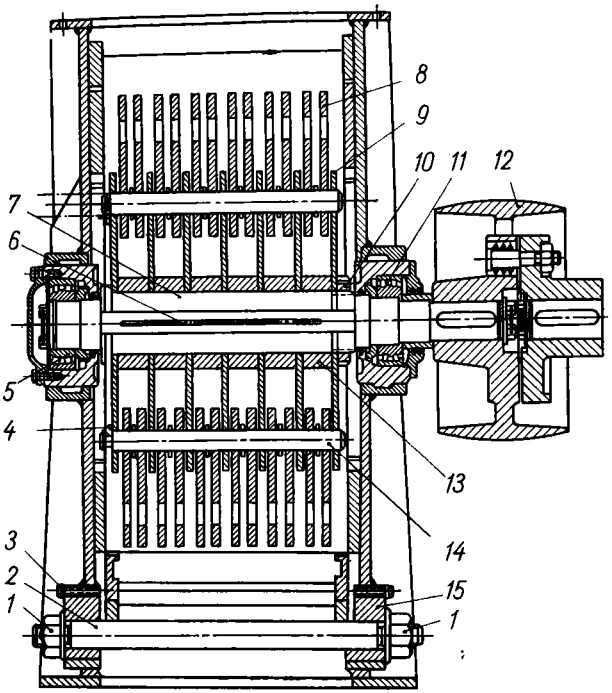


Fig. 127. CM-18 hammer mill rotor:
1—nuts, *2*—rod, *3*—set screw, *4*—cross bar, *5*, *11*—bearings, *6*—key, *7*—shaft, *8*—hammers, *9*—disks, *10*—nut, *12*—coupling, *13*—spacer, *14*—pin, *15*—eccentric ring

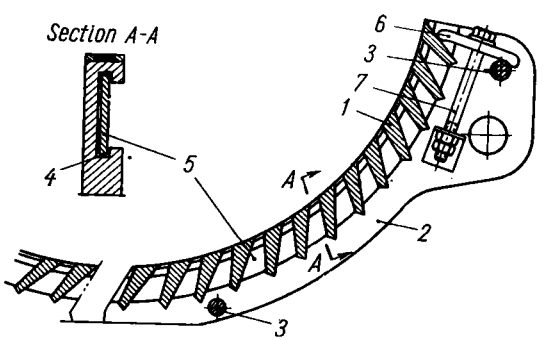


Fig. 128. CM-18 hammer mill grate:
1—bars, *2*—arc-shaped supports, *3*—stay rods, *4*—groove, *5*—distance piece, *6*—strap, *7*—bolt

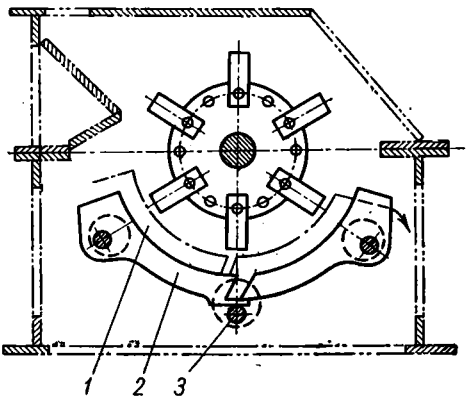


Fig. 129. Grate adjustment in CM-18 hammer mill:
1—upper position of grate, *2*—grate in lower (initial) position, *3*—eccentric rings for changing position of grate

Adjust the clearance between rotor and grate depending on the grade and properties of the material to be crushed and the crushing requirements.

Hammer Mill Operation. Feed the mill uniformly. Start feeding only after the rotor has built up its rated speed; if during operation the rpm begins to drop, stop the feed and allow the rotor to regain speed.

Keep an eye on the bearings and see that they are amply lubricated.

Check the condition of the grate regularly and clean it if it gets clogged.

Before switching off the motor stop the feed to the mill.

Installation of Hammer Mills. The mill is delivered fully assembled and should be set upon a concrete foundation. To reduce vibration place a frame of square-sawn timber between the foundation and the mill housing base. Check the position of the mill with a level set on the housing.

When installing the motor take care that the belt is well trained, that the distance between the motor and mill shafts is in accordance with hints given above.

When installing the machine check the fastenings of the disks, hammers, breaking and armour plates, and grate; adjust the clearance between grate and hammers.

Before starting make sure the machine is lubricated, and after connecting the motor to the source test it first under no load, and then under load.

26. Sizing and Washing Machinery

Materials such as crushed stone, gravel and sand are sorted into several grades according to lump (grain) size. This operation is called sizing.

In civil engineering practice sizing is mostly done by mechanical means. Mechanical sizing is achieved by sifting the materials through screening surfaces.Machines on which materials are sized in this way are called *mechanical screens* or just *screens.*

Screens may have flat or cylindrical screening surfaces; in the latter case the machines are called *trommels.* In flat screens the material covers the whole screening surface during operation and therefore it is sized better and more quickly than in trommels.

Sand, gravel and crushed stone used in civil engineering must be freed from impurities. This is accomplished simultaneously with sizing by washing on the screens, or by washing in special machines (washers). The former method is used for materials containing insignificant amounts of impurities, and the latter, when the impurity content is high.

When washing on screens, water is sprayed under pressure from pipes over the entire width of the layer of material as it is being sized, washing away the impurities.

When washing is done on special machines the water moves under head towards the oncoming impure material, gradually carrying away the impurities as it goes along.

Technical data on screens are given in Table 19.

C-96A Eccentric-Drive Screen (Fig. 130). This screen is intended for sizing crushed stone, gravel and sand, and for removing undersize and dust. The material may be washed on this screen as it is being sized.

The screen consists of a fixed main frame *3*, a movable screen box *2*, three decks (screen cloths) *1*, and an eccentric shaft *9*.

The *main frame 3* is a welded construction made of channel iron. It is suspended from rods or fixed to a bedplate.

The *movable screen box 2* is made of sheet and angle steel. The box body is installed at a slope which can be varied between 17 and 22°, and is supported by springs. *Three screen surfaces 1* are stretched across the screen box.

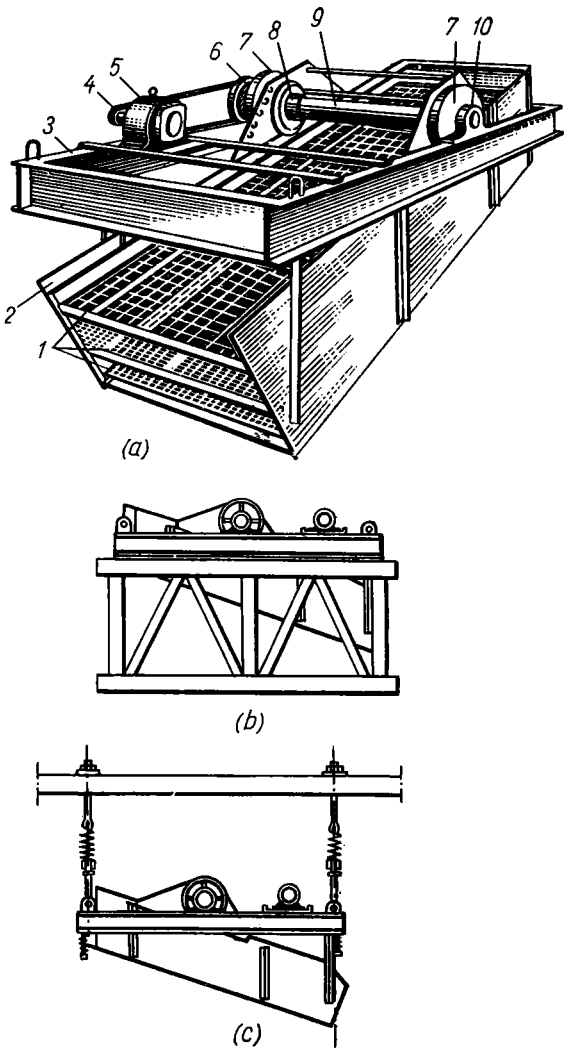


Fig. 130. C-96A eccentric-drive screen:
(*a*) general view, (*b*) installation on wooden framework, (*c*) installation on steel hangers; *1*—decks, *2*—screen box, *3*—main frame, *4*, *6*—pulleys, *5*—motor, *7*—flywheels, *8*, *10*—bearings, *9*—shaft

Table 19

Screen Specifications

Item	Eccentric-drive type				Unbalanced-throw type
	CM-570	CM-571	CM-572	C-96A	CM-13
Capacity, m^3/hr	55-85	85-130	up to 300	16	40
Screen size, mm	1,000× ×2,500	1,200× ×3,000	1,500× ×3,750	750× ×2,000	upper 2,400× ×950, lower 1,200×940
Number of decks	2	2	2	3	2
Shaft rpm	1,400	1,300	875	1,200	740
Motor rating, kW	4.5	7.0	14	4.5	5.2
Overall dimensions, mm:					
length	—	—	—	2,887	1,919
width	—	—	—	1,360	3,153
height	—	—	—	1,480	1,226
Weight, kg	1,850	2,850	7,854	970	1,715

The *eccentric shaft 9* rotates in two ball bearings *10* secured on the fixed main frame. The shaft has two eccentric necks enclosed in ball bearings *8* which are mounted on the side walls of the screen box *2*.

Flywheels *7* with counterweights are provided on the shaft between bearings *10* and *8*.

The eccentric shaft is rotated by an electric motor *5* mounted on the fixed main frame, through the agency of a V-belt drive consisting of drive pulley *4*, three V-belts and driven pulley *6*, which is keyed to the end of the eccentric shaft.

Fig. 131 shows the left *A* and right *B* ends of the eccentric shaft *1*. Included in *A* are bearings *6* of the main frame *3* and the movable screen box bearings *8*, flywheel *7* with counterweight *4*, and driven V-belt drive pulley *5*. *B* shows only the bearing *2* on the main frame *3*.

Rotation of the eccentric shaft makes the screen box shake vigorously. However, owing to the flywheel with its counterweight the vibrations of the screen box are not transmitted to the main frame and the bearings mounted on it.

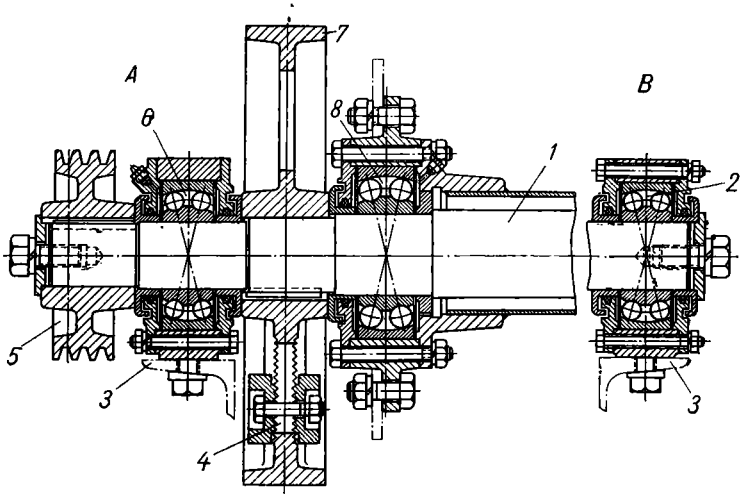


Fig. 131. Eccentric shaft of C-96A screen:
1—shaft, *2*, *6*, *8*—bearings, *3*—main frame, *4*—counterweight, *5*—pulley; *7*—flywheel

Material is fed to the screen by means of feeders, the design of which depends on the kind of material being sized.

The sized products gravitate down chutes having a slope of 30 to 40°.

Installation of the Screen. The screen is delivered to the site of operation fully assembled. It may be set on a timber framework or hung from steel rods with springs.

If set on a framework, place rubber gaskets 25-30 mm thick under the fixed main frame and under the foundation bolt washers. If suspended from steel rods, make sure the latter are strictly vertical.

When set on a framework the slope of the screen box can be varied between 17 and 22° by adjusting the end springs. When suspended, the slope is changed by increasing the length of the front rods connected to the eyes on the main frame.

After installing the screen check the positions of the counterweights on the flywheels (taking advantage of the red control lines) and see that they are bolted tightly to the flywheels; check the slope of the

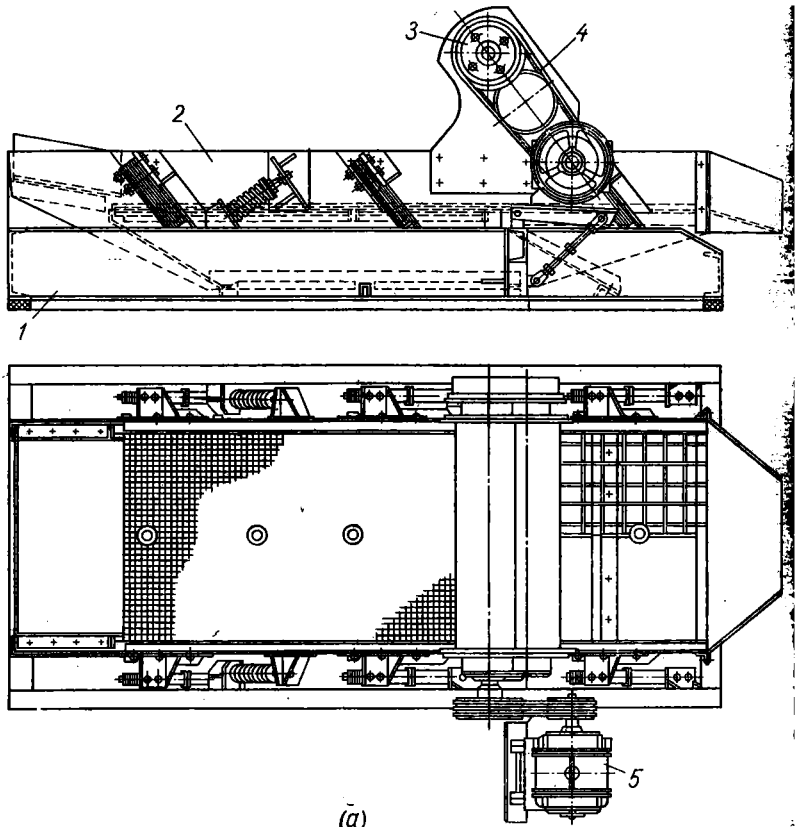
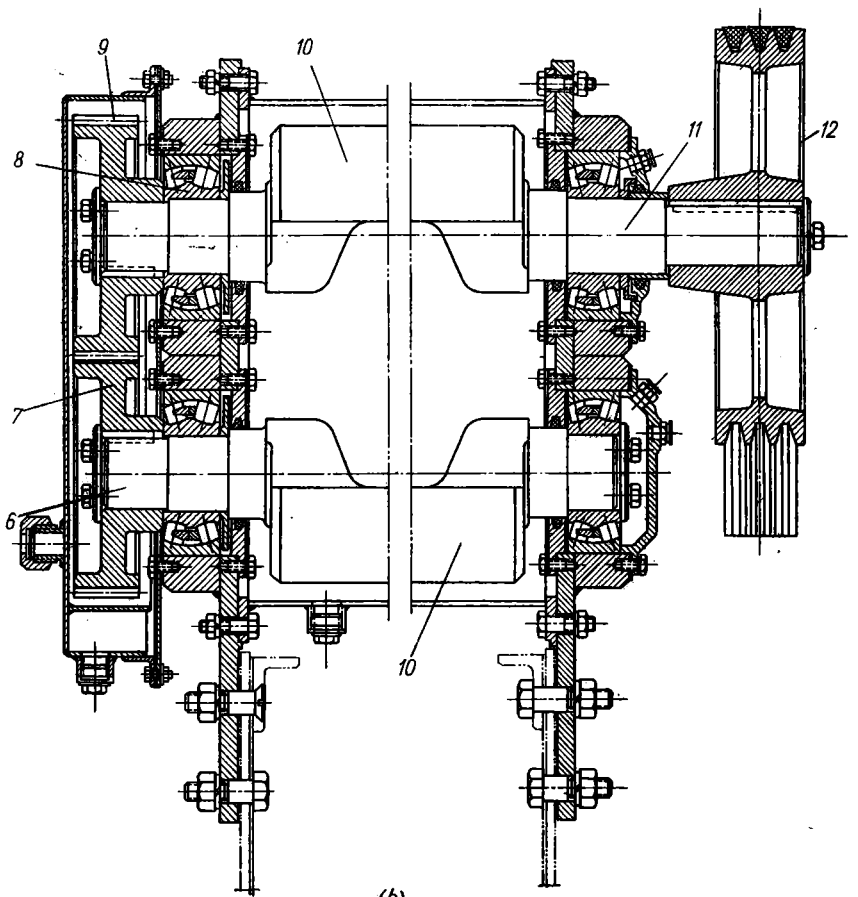


Fig. 132. CM-13 unbalanced

(*a*) schematic diagram of screen, (*b*) screen vibrator; *1*—fixed frame, *2*—screen box



throw screen:

3 vibrator, 4—drive, 5—motor, 6, 11—shafts, 7, 9—gears, 8— earings, 10—weights; pulley

screen box against catalogue data, the tension and fastenings of the springs on the screen box, the fastenings of the upper deck, the fastenings of the eccentric shaft bearing housings and all bolt fastenings.

Then put the product chutes in place, install the starting equipment and connect the motor to a suitable current source.

After installation test the screen first without load, and then under load.

CM-13 Unbalanced-Throw Screen (Fig. 132*a*). The main parts of the screen are: fixed frame *1*, movable frame (box) *2*, vibrator *3*, V-belt drive *4*, motor *5*.

The *fixed frame 1* is made of channel iron and is secured to a foundation with six bolts. When installing, a rubber gasket 40 mm thick is inserted between the frame and the foundation to prevent vibration of the foundation during operation.

The *movable frame* (*box*) *2* is in the form of a tray made of sheet steel.

The box is secured to the fixed frame through flat springs set at 55° to the horizontal.

The box contains an upper screen deck 2,400 × 950 mm in size with 32-mm apertures, a lower one 1,200 × 940 mm in size with 7-mm apertures, and a supporting grating 1,200 × × 950 mm in size with 40-mm openings.

The *vibrator* (Fig. 132*b*) consists of two parallel shafts *6* and *11*, rotating in opposite directions, with eccentrically arranged weights *10* in their middles. The shafts are supported by roller bearings *8* the housings of which are mounted on the screen box. These shafts are connected by a gear drive consisting of two spur gears *7* and *9*. Thus, rotation of shaft *11* will cause rotation of shaft *6* in the opposite direction. This causes linear vibrations of the vibrator, and therefore, also of the screen box to which it is fixed. As the plane passing through shafts *11* and *6* has a slope of 55° to the horizontal, the direction of the vibrations will be at an angle of 35° to the horizontal.

The shafts and gears are enclosed in sheet steel housings.

A V-belt pulley *12* is keyed to the end of shaft *11* projecting from the bearing.

The screen *drive mechanism* consists of an electric motor *5* and a V-belt drive including a drive pulley seated on the motor shaft, three V-belts and the driven pulley on the vibrator shaft.

Shaft *11* driven by the V-belt drive does 740 rpm, and vibrator shaft *6* rotates at the same speed.

CM-652 and CM-653 Vibrating Screens (Fig. 133). These heavy-duty vibrating screens are intended for mechanical sizing of materials.

Besides sizing, materials contaminated with clay, dust and other impurities can be washed on these vibrating screens.

Technical data on the screens are listed in Table 20.

Table 20

Specifications of Vibrating Screens

Item	Model	
	CM-652	CM-653
Capacity, m^3/hr	150	200
Number of decks	2	2
Size of feed, mm	up to 150	up to 150
Screen dimensions, mm:		
width	1,500	1,750
length	3,750	4,500
Aperture, mm:		
upper deck	22×22	22×22
lower deck	5×20	5×20
Drive shaft rpm	875	800
Motor:		
type	AO62-4	AO62-4
power rating, kW	10	10
rpm	1,460	1,460
Slope of screen, deg	30	30
Weight without motor, kg	5,060	5,765

On heavy-duty vibrating screens the material is separated into fractions as it moves down inclined screening surfaces performing circular vibrations in a vertical plane.

The movable frame is vibrated by means of an eccentric shaft.

The direction of rotation of the drive shaft may be with-flow or con-flow. Upon with-flow rotation the throughput

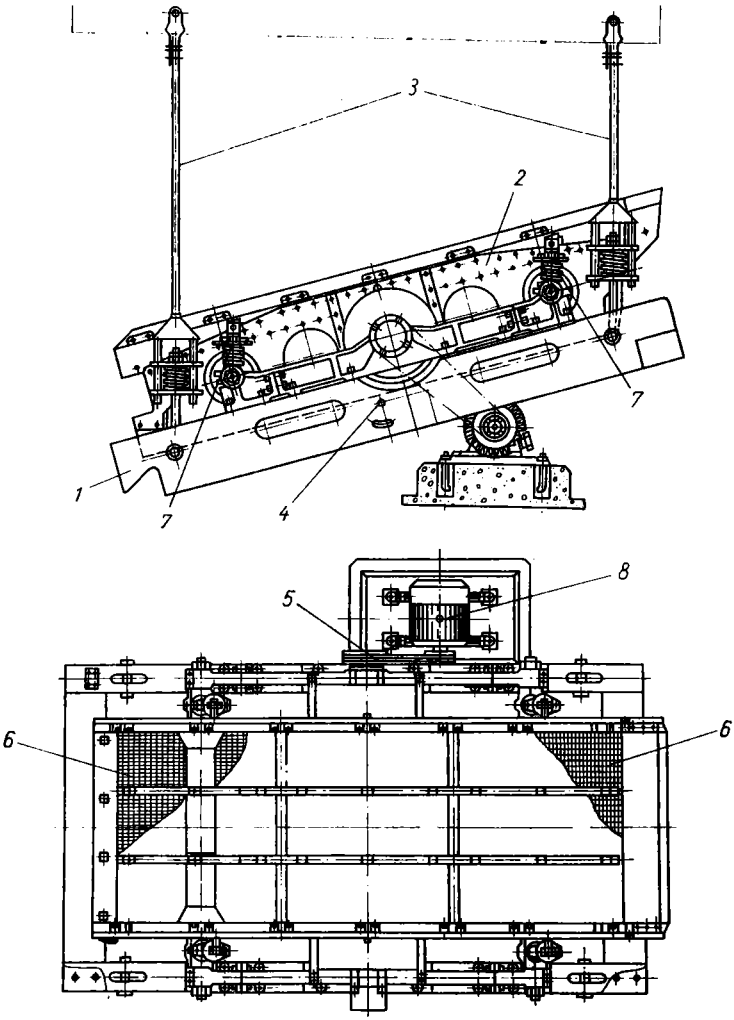


Fig. 133. CM-652 vibrating screen:
1—fixed frame, *2*—movable frame, *3*—hangers, *4*—drive shaft, *5*—V-belt drive, *6*—screen cloths, *7*—springs, *8*—motor

of the screen is higher than with con-flow rotation, but con-flow ensures better-quality screening.

Heavy-duty vibrating screens consist of the following chief elements: fixed main frame *1*, screen box *2*, vibrator, auxiliary support axles and hangers *3*. The main frame serves as the base of the screen. It may be set on a foundation or suspended from special metal structures or ceiling girders. Bolted to the main frame are yokes which serve as supports for the drive shaft bearings and for the axles of the auxiliary rubber supports. The main frame also carries the guards covering the flywheels, the V-belt drive *5* and the projecting end of the drive shaft *4*.

The main frame is a welded construction made of channel iron.

The screen box is a riveted and welded construction. It is assembled from side sheets, cross ties, inside longitudinal and back walls. On it are bolted the bearing housings of the drive shaft and the auxiliary rubber supports. The screen box also carries the screen cloth *6*.

Besides being fixed to the side walls, the drive shaft and auxiliary rubber support bearings are tied in pairs with transverse tubes which lend stiffness to the screen box and protect the drive shaft and auxiliary support axle from wear.

The side and inside walls, cross ties and tubes have wear-resistant guards.

The lower part of the back wall is removable, giving access to the screening surfaces.

The screen box has brackets fixed to it, by means of which the box rests on four helical springs *7*. These springs are supported by the auxiliary support axles and serve to balance the weight of the screen box and to relieve the rubber auxiliary supports. The vibrator shaft passes through the centre of gravity of the screen box. The eccentric shaft journals carry roller bearings which are mounted in housings fixed on the screen box.

When the drive shaft rotates the screen box performs circular vibrations at a frequency equal to the rpm of the shaft and a throw equal to twice the eccentricity.

The shaft is also supported by roller bearings mounted on the yokes of the main frame.

The bearings have a combined seal consisting of special reinforced rubber cup-type packings and labyrinths.

The bearings are furnished with pressure lubricators which are screwed into the bearing housings.

Rotation of the shaft causes centrifugal forces. To balance them the shaft carries two flywheels with two counterweights each.

The screen box rests on the rubber auxiliary supports. There are four such supports, and they ensure circularity of the screen box vibrations. The support axles are fastened rigidly to the yokes on the main frame. Each support is a rubber disk of variable cross section with an outer and an inner metal ring. By means of their outer rings the supports are inserted in housings which are riveted to the sides of the screen box; the inner rings serve to hold the supports on the fixed axles to which they are tightened with nuts through intermediate boxes. The axles are cleated to the yokes.

The intermediate boxes set on the axles serve simultaneously as supports for four helical springs.

On the CM-652 and CM-653 screens these boxes consist of two halves (upper and lower).

The auxiliary support casings have threaded holes through which the rubbers can be pressed out during disassembly.

When assembled these holes are closed by screws to keep dust and grit out of the casing.

The screens are installed either on base frames or foundations, or are suspended by special hangers.

The screens are actuated by induction motors *8* through V-belt drives *5*.

The motor is set on rails which are independent of the screen installation. The V-belt drive is enclosed with a safety guard.

Installation of Screen. Screens are usually delivered from the manufacturing plant completely assembled except for the motor, V-belt drive and starting equipment.

The screen should be set on a foundation (or special frame); the fixed main frame of the screen is secured to the foundation with eight bolts. It is better practice to suspend the screen on hangers.

Independent of the method of installation of the screen (on a bed frame, foundation or hangers) the main frame must be levelled out very carefully to avoid skewing. Skews result in nonuniform distribu-

tion of the load on the auxiliary supports, springs and bearings. The feed and product chutes must not be fastened to the screen box, as this will disturb the mass equilibrium of the box and flywheels, and the drive shaft will no longer pass through the centre of gravity of the vibrating parts, resulting in faulty operation.

The tilt of the screen is adjusted by inserting wedges between the base (foundation or bed frame) and the main frame, or by means of turnbuckles, if the screen is suspended.

C-213A Gravel Washing Trommel (Fig. 134). This machine is intended for washing and sizing gravel and crushed stone; it is used for washing and sizing slightly and moderately contaminated materials. Technical data on the

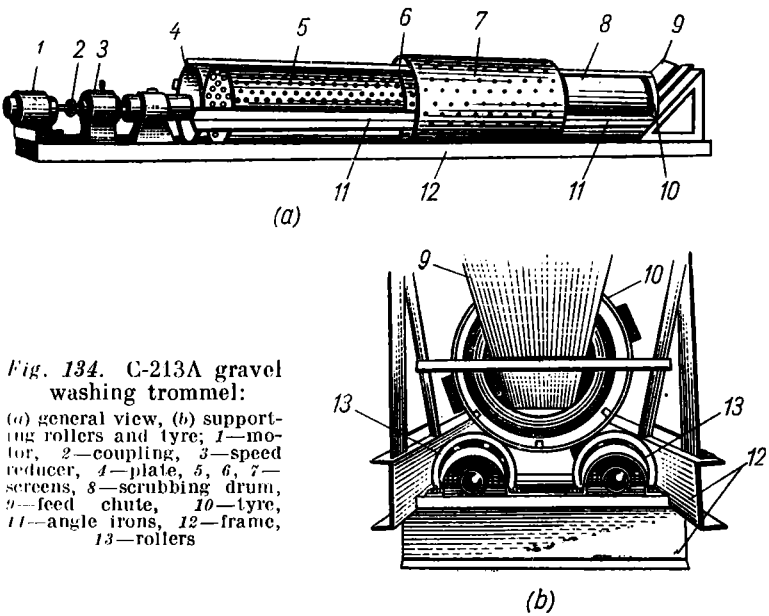


Fig. 134. C-213A gravel washing trommel:
(*a*) general view, (*b*) supporting rollers and tyre; *1*—motor, *2*—coupling, *3*—speed reducer, *4*—plate, *5*, *6*, *7*—screens, *8*—scrubbing drum, *9*—feed chute, *10*—tyre, *11*—angle irons, *12*—frame, *13*—rollers

C-213A gravel washing trommel, as well as the C-215Б, a machine of the same type, and the C-244A gravel sizer are given in Table 21.

Gravel washing trommels consist of the following chief components: shell, supports, drive, motor, feed chute and frame.

Table 21

Specifications of Gravel Washing Trommels and Gravel Sizer

Item	Gravel washing trommels		Gravel sizer
	C-215B	C-213A	C-244A
Capacity, m^3/hr	37-45	9-11	9-11
Maximum lump size in feed, mm	100	80	80
Number of sizing sections	3	2	2
Outer shell diameter, mm	1,400	870	870
Inner shell diameter, mm	1,000	600	600
Aperture size, mm:			
first section	20	20	20
second section	20	40	40
third section	40	—	—
Aperture size of outer drum, mm	6	6	6
Shell rpm	15.1	20	20
Shell incline, deg	6	6	6
Motor power rating, kW	4.5	1.7	1.7
Water requirements, m^3/hr	30-75	10-25	—
Overall dimensions, mm:			
length	6,900	5,610	4,555
height	1,540	1,200	1,200
width	1,740	1,135	1,135
Weight, kg	2,482	1,060	860

The *shell* consists of two sections: a scrubber and a trommel. The scrubber *8* is a sheet steel cylinder to which a cast steel tyre *10* is welded. The cylinder is partitioned off into four chambers. Its inside surface has sheet steel blades welded to it parallel to one another.

The trommel or sizing section consists of three cylindrical screens. Screen *6* with 20-mm apertures and screen *5* with 40-mm apertures follow the scrubber in succession, while screen *7* with 6-mm apertures encircles screen *6*.

The shell carcass is made of four lengths of angle iron, one end of which is fixed to the tyre *10* and the other to an end plate *4* with a journal. The screens *5*, *6*, and *7* are fastened to the carcass angles *11*.

The scrubber tyre *10* rests on two supporting rollers *13*, while the other end of the shell is supported by the journal of plate *4*, which rests on a bushing with a spherical support, this being enclosed in a split bearing.

The shell is rotated by an electric motor *1* through the agency of a speed reducer *3* and a pair of gears, one of which is seated on the reducer shaft, and the other on the journal of plate *4*. The motor shaft is connected to the reducer shaft by means of a coupling *2*.

The *feed chute 9* leads the feed material into the scrubber. It is arranged so that it extends inside the shell through the feed aperture. This chute has a pipe fixed to it which passes through the scrubbing section into screen *6*. The pipe has a branch (manifold) on its end with 5-mm apertures through which water is sprayed on to the screen.

The *frame 12* is a welded construction made of channel iron. It carries the supporting rollers, the bearing, the speed reducer, the motor and the feed chute.

Operation of the gravel washing screen is as follows. The material is fed through the feed chute to the first scrubber chamber; as the shell rotates the material is caught up by the blades and owing to the incline of the shell moves gradually from one chamber to the next, being mixed and washed at the same time. The washed gravel then passes into the first sizing section with 20-mm apertures.

The water drains out the discharge end of the scrubber and through the screen apertures together with the clay particles and other impurities that have been washed off. On the first screen the fraction with lumps smaller than 20 mm is separated out of the washed mass and falls on the outer screen where the fraction with grains smaller than 6 mm is screened out of it. The water spray aids the separation of the sand from the gravel and its passage through the apertures of the outer screen.

The lumps of gravel larger than 20 mm which did not fall through the first screen pass on to the second screen with 40-mm apertures, through which the lumps from 20 to 40 mm in size drop. The lumps over 40 mm in size which did not pass through the apertures of the second screen, are discharged at the end of the shell. Thus, in passing through the shell the material is separated into four size

grades: sand up to 6 mm, gravel from 6 to 20 mm, from 20 to 40 mm and coarser than 40 mm.

Installation of Gravel Washing Trommel. The gravel washing trommel is delivered to the construction site completely assembled.

Install the shell at a convenient height to allow for discharge of the sized material from the screens on to the conveying appliances and for drainage of the dirty water. Usually the shell is placed over a bin with separate compartments for the various gravel or crushed stone sizes. The bin compartments are furnished with gates for periodic discharge of the material into transport conveyances.

Dirty water is drawn off together with the sand through a launder to waste or (if the sand is to be used) to devices for separating the sand.

The shell should have a slope of 5-6° towards the discharge end; for this purpose place the timber supports on which the shell is set at an incline. The shell does not vibrate substantially during operation, and it may be fastened to the longitudinal timber supports with four yokes of 16-mm round steel with threaded ends for nuts.

Water is fed to the shell through a $2^1/_2''$ pipe connected to the shell water feed pipe.

Set a launder of rectangular cross section 250-300 mm wide under the outer shell to carry away the dirty water; the bottom of this launder should have a slope of not less than 20°, and the bottom of the draw-off part of the launder—not less than 10°.

After installing the machine, grease the drive and the supporting rollers, then connect the motor and check the direction of rotation. The shell should rotate clockwise if regarded from the feed end.

Fix a skirtboard of sheet steel along the left-hand longitudinal beam 300 mm high to prevent splashing.

C-387 Gravel Scrubber (Fig. 135). This machine is intended for washing gravel that contains considerable amounts of clayey impurities. The main component of the gravel scrubber is the rotating cylindrical shell *5*. The shell is supported by means of two tyres *6* resting on four rollers *11* mounted on supports *12* on the frame *9*.

The shell has openings in its end walls, a feed opening with a hopper *7* and a discharge opening with a receiver *3* and chute *13*. The inside surface of the shell is covered with liners *10* which protect it from wear by the gravel as it is mixed. Water is fed to the shell through pipes *1* and *8*.

The scrubbed material falls into the pockets formed between the ring *4* and the grates welded to the discharge end wall of the shell; as the shell rotates, the material rises and slides down the inclined pocket into the discharge opening, and thence into dewatering trommel *2* from which it drops into a bin or on to a conveyor belt.

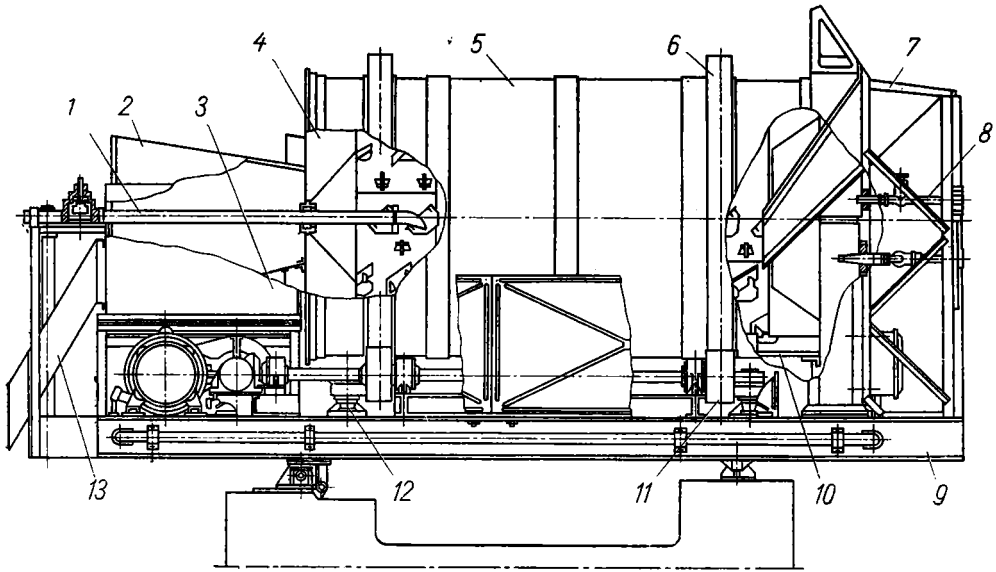


Fig. 135. C-387 gravel scrubber:

1, *8*—water pipes, *2*—dewatering trommel, *3*—receiver, *4*—ring, *5*—shell, *6*—tyres, *7*—feed hopper, *9*—frame, *10*—liners, *11*—rollers, *12*—supports, *13*—discharge chute

Specifications of C-387 Gravel Scrubber

Inside shell diameter, mm	2,000
Working length of shell, mm	3,600
Shell rpm	11.5
Slope, deg	3-5
Throughput, m^3/hr	100
Maximum lump size in feed, mm	up to 150
Water requirements per cu m of washed material, m^3	2
Motor:	
power rating, kW	28
rpm	1,420
Overall dimensions, mm:	
length	6,780
width	2,635
height	2,955
Weight, kg	12,600

27. Brief Information on Crushing Plants

Crushing plants are intended for converting rock into crushed stone and for separating the latter into size fractions. Washing and sizing plants are intended for separating the gravel from a sand-gravel mixture and washing it.

These plants may operate according to various flow sheets. They are set up at quarries—places where rock suitable for making crushed stone is won, and at gravel deposits.

When the quarries are located near the construction site the crushed stone or gravel is delivered to the site of its consumption by tip-up lorries or self-dumping railway cars; if the quarries are far away from the construction site the products are shipped to the site by rail or waterway.

Preparation of the crushed stone falls into several operations: crushing, sizing, and storage. Depending on the lump size of the feed, crushing may be single-stage, double- or two-stage, triple- or three-stage, and sometimes quadruple- or four-stage. If the crushed stone contains more clay than the consumer will tolerate, a washing step is added.

Single-stage crushing (Fig. 136*a*) is employed at plants of capacities up to 30 tons per hour.

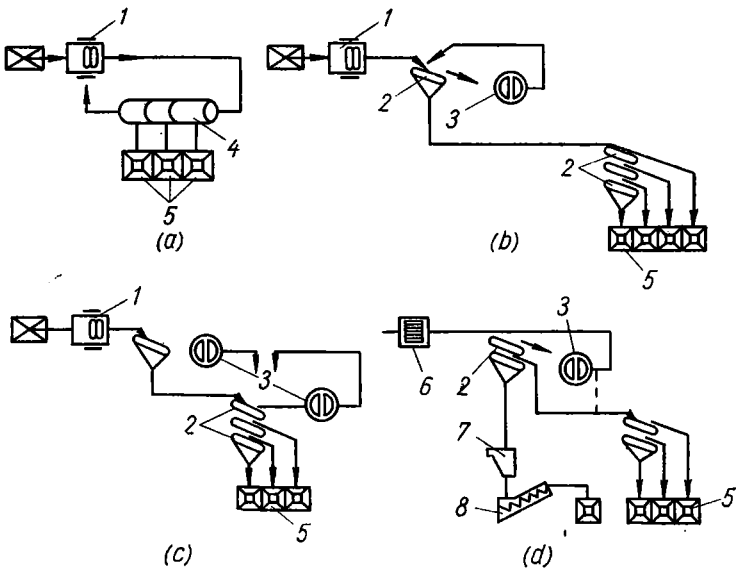


Fig. 136. Flow sheets of crushing-and-sizing and washing-and-sizing plants:

(*a*) single-stage rock crushing plant, (*b*) ditto, two-stage, (*c*) ditto, three-stage, (*d*) flow sheet of washing-and-sizing plant; *1*—jaw crusher, *2*—vibrating screen, *3*—cone crusher, *4*—trommel, *5*—bins, *6*—bin with grate, *7*—settling tank, *8*—sand washing machine

Single-stage crushing is done by jaw breakers with a feed opening of 400 × 600 mm. In this case the crushed products are stored in bins after sizing, while lumps larger than required are returned to the same breaker for recrushing. Two-stage crushing (Fig. 136*b*) and three-stage crushing (Fig. 136*c*) are employed at plants with capacities from 30 to 1,000 tons per hour.

In the first crushing stage rocks up to 1.5 m in size are reduced to 200-300 mm in jaw breakers; in the second stage cone crushers reduce the lumps to 80-100 mm and in the third similar crushers (of the shorthead type) crush them to 50 mm or less.

The primary crushing section is equipped with jaw breakers, feeders and belt conveyors; the secondary crushing section, with cone crushers, screens for sizing the crushed

material, belt conveyors for taking the crushed stone to storage or to the screening and washing section; the latter section includes equipment for separating the crushed stone into size fractions and machines for washing it.

The sized stone is conveyed to storage which is equipped with stackers, power shovels and bulldozers; the crushed stone is loaded into the transport conveyances by means of power shovels or with special equipment.

At places where gravel is excavated gravel sizing plants (Fig. 136*d*) are set up, which may include units for washing the gravel mixture.

The flow sheets of these plants may provide for the production of finished aggregates for making the concrete mix, or may be restricted to gravel separation. Their layouts may include receiving bins for gravel mixtures with feeders for sending the mixture to the sizing unit, and a system of belt conveyors and feeders. If the mixture contains stones more than 250 mm in size, the latter are scalped off with single-deck screens as the mixture is discharged from the bins, after which they are crushed and passed on to the sizing units, which consist of a system of screens for separating the gravel into size fractions, a sand washer (if washing is required), a system of belt conveyors for taking the gravel to storage, equipment for feeding and draining water, gravel storage with loading and unloading equipment.

Products put out by small-capacity crushing and sizing plants are known to be dear. That is why there is a tendency at present to stop building small-capacity crushing and sizing plants.

The minimum size of plants at which rock materials can be crushed and sized profitably is 400 thous. cu m per year.

The present trend in the rock industry of the U.S.S.R. is to expand through the erection of large-capacity enterprises with an annual throughput of from 600 thousand to 1,200 thousand cubic metres. Such an enterprise is able to meet the demands of an entire construction district.

This trend in the development of rock industry enterprises determines the tendency in the manufacture of crushing and sizing equipment, which is to increase the output of large-size, high-capacity machinery and to decrease that of small machines.

CHAPTER SIX

MAINTENANCE AND REPAIRS

The interaction between the parts of a machine during its operation, or between the machine elements and the materials machined results in deterioration of the parts, meaning destruction of their working surfaces. Changes occur in the structure of the metal in the layers adjacent to the friction surfaces, in the shape and size of the part and in the finish of its working surface.

Most liable to wear are such elements as the journals of shafts, the teeth of gears, mixing blades, etc.

Such deterioration is a natural phenomenon, and the attendant wear is natural wear of the parts. As the parts deteriorate their wear increases and the machine loses its performance qualities. Limit wear is the extent of wear after which further operation of the element, set or machine becomes unreliable.

The intensity of wear of machine elements depends on the conditions under which the machine is operated.

One of the important factors for reducing the intensity of wear is organization of timely and expert maintenance of contractor's machinery, on which the service life of the parts, units and machines depends.

Hence, the purpose of machine maintenance is to reduce the intensity of wear and to take timely measures for eliminating its influence on the performance of the machine.

28. Machine Maintenance

The maintenance required by a machine in the course of its lifetime is of two kinds, namely, maintenance during operation and maintenance during transportation and storage.

Machine maintenance during operation consists in cleaning and inspecting the machine, checking the work of and repairing its lubricating devices, lubricating the machine, tightening up the connections between components, replacing lost and spoiled fasteners, checking the performance of and adjusting starting, friction and braking mechanisms, checking the state and tension of belts, chains, ropes, their points of connection and fastening and replacing them if necessary; checking the performance of the machine as a whole; checking the presence and state of guard devices, priming with lubricants, fuel, water, etc.

During machine operation, one distinguishes between shift maintenance and periodical maintenance, depending on the nature and volume of the work involved and the time required to fulfil it.

Shift maintenance includes work that is carried out each shift: before the shift begins, during the shift and after it.

The typical operations of this kind of maintenance are as follows. Before shift begins: inspect the machine, lubricate, prime with water and fuel and test; during shift: inspect, clean, tighten parts and adjust units if necessary; after shift: clean, inspect, tighten parts, restore seals, adjust units, and test individual mechanisms if necessary. When inspecting the operation of individual details of a mechanism, lubricating, adjusting and eliminating trouble, stop the machine. If fasteners get lost or injured replace them with new ones. If defects are detected in the mechanisms while inspecting and testing them, eliminate them; notify the repair mechanic or electrician if necessary. After eliminating the trouble test the machine, disconnect the motor and lock up the starting equipment and the operator's booth; in cold seasons drain water from all piping, cylinders and radiators.

Periodic maintenance work is done at intervals covering a definite number of hours of machine operation, between shifts, or during down hours for repairs if they come due at the same time.

Periodic maintenance includes the same operations as shift maintenance plus lubrication, replacement of seals, ropes, belts, etc.

It is evident from the list of jobs included in machine maintenance that these jobs are prophylactic in nature, serving to prevent rapid deterioration of machine elements, i.e., to lengthen their service life. Timely lubrication of machines is especially important, since lubrication reduces the friction between moving parts and keeps them from wearing out.

Maintenance during machine operation is obligatory and must be done at the time specified.

Maintenance during machine operation is the duty of the contractor's machine operator who is aided in this by repair fitters and electricians. Hence, the operator is responsible for the state of the machine and its trouble-free operation.

Machine maintenance during transportation and storage consists in observing the transportation and storage rules stated in special instruction books and leaflets.

For transportation by rail large-size machines must be dismantled into parts conforming in weight and overall dimensions to the requirements of the Ministry of Transport; the individual parts of the machines should be well greased, and the instruments and small parts packaged.

Machines should be stored in conditions eliminating the possibility of spoilage due to atmospheric attack and temperature changes.

LUBRICATION

Lubrication is one of the most important items of maintenance; most trouble and breakdowns of machines can be traced to nonobservance of the specified lubrication schedule and the use of improper lubricants.

The functions of lubrication are as follows:

(1) it reduces friction between the surfaces of mated moving parts, and therefore, lowers energy losses due to friction;

(2) it slows down the wear of parts by changing the type of friction, removing heat from parts which tend to get hot during operation, and keeping grit out of the clearances between parts;

(3) it protects parts from corrosion;

(4) it reduces shocks between mated parts.

For the lubricant to be able to fulfil these functions, it must meet certain requirements, the most important of which are:

(1) oiliness to ensure the formation of a strong film on the lubricated parts;

(2) viscosity depending on the conditions of operation;

(3) viscosity must not drop sharply with rising temperature;

(4) thermal stability, i.e., the ability of the lubricant to resist high temperatures;

(5) resistance to oxidation by atmospheric oxygen and ability to retain its properties as unchanged as possible during storage;

(6) low congealing point;

(7) low volatility and high flash point;

(8) complete absence of mineral acids and alkalis and minimum content of organic acids;

(9) minimum content of mechanical impurities and water.

Lubricants are selected depending on the pressure per unit of friction surface area, speeds, finish of the rubbing surfaces, temperature, shape and nature of the junction. Hence, when selecting a lubricant, the operating duty of the mated parts, the degree of their wear and the specific features of operation should be taken into account.

An increase in the pressure, speed, ambient temperature or the clearance between the parts will require the use of an oil of higher viscosity. Heavy-bodied oils have low mobility in winter and a higher congealing point. That is why heavier-bodied oils are employed in summer, and lighter-bodied in winter.

Worn parts require the use of heavier-bodied oils.

Assemblies working under high pressures per unit of area require heavier-bodied oils; assemblies working at high speeds require lighter-bodied ones.

At considerable speeds an excessively viscous lubricant will cause overheating of bearings.

If the bearings operate under elevated temperatures an oil should be used that retains the necessary body at those temperatures.

Some basic points on the lubrication of certain machine assemblies are given below.

Roller and ball bearings. Lubricants should be selected for roller and ball bearings depending on their location in the machine and working conditions (pressure per unit of area, peripheral speed).

Roller and ball bearings of speed reducers operating at 4-8 m/s are lubricated with automobile transmission gear oil (GOST 542-50); for roller and ball bearings of other assemblies, with speeds up to 0.3 m/s, УС$_С$-1 and УС$_С$-2 grade cup greases are suitable.

Sleeve bearings. When selecting lubricants for sleeve bearings, the pressure per unit of area, peripheral speed, bearing and ambient temperatures should be taken into account.

УС$_С$-1 and УС$_С$-2 grade cup greases and konstalins may be used as lubricants for sleeve bearings, cup grease being suitable for assemblies operating in a moist atmosphere at temperatures up to 50°C, and konstalins, for bearings working in a dry atmosphere at temperatures over 50°C.

Hinges and bushings. Hinges and control bushings are usually lubricated with УС$_С$-1 or УС$_С$-2 cup grease.

Drive chains. Lubricants for drive chains are selected depending on the pressure per unit of area in the joints, chain speed and method of lubrication. Industrial oil 45 or 45B is used for chain drives.

Chain link joints should be greased with consistent grease every 120 to 180 hours of operation of the chain; in a moist atmosphere cup grease should be used, otherwise, konstalin.

Lubrication of ropes. Steel ropes are greased to reduce friction between strands and to prevent corrosion.

Before greasing, ropes should be cleaned with a stiff brush and wiped dry with a cloth. Rope grease should be heated before being applied with a brush or rubbed in with a cloth.

A substitute for rope grease is a mixture of 90 to 95 per cent of cup grease and 5 to 10 per cent of grade III bitumen, preheated to 60°C.

Contractor's machinery ropes should be greased approximately every 50 hours of operation of the machine.

In storage, ropes should be inspected and greased not less frequently than once a year.

If kept in storage for a long time a rope will lose elasticity. Before employing such a rope in the machine it

should be impregnated for 24 hr with spent lubricating oil heated to 60-65°C with 4-5 per cent of copper sulphate, 8 per cent of rosin and 2 per cent of soda added. The copper sulphate protects the core of the rope from rotting.

Gear and worm drives. Either oil or consistent greases may be used for gear and worm drives, depending on the working conditions, the design of the unit and the method of applying the lubricant.

The usual lubricant for enclosed gear drives is nigrol.

The lubricant for open gear drives is УСА graphite grease or a mixture of 90 per cent cup grease and 10 per cent graphite.

The service life of a lubricant depends on the working conditions of the unit.

The properties of a lubricant change during operation. The lubricating properties deteriorate (this being referred to as ageing of the oil) for the following reasons:

(1) appearance of metallic dust in the oil owing to abrasion of the rubbing parts;

(2) formation of oil oxidation products;

(3) contamination with foreign abrasive particles.

The net result is that the oil becomes unsuitable for further use and must be replaced.

Besides, during machine operation oil leakage, partial squeeze-out and throw-off of grease is likely to occur, oil is lost by burning in internal combustion engines, etc. Hence, lubricants should be replenished in due time.

The lubricant is added as required. The better the design of the machine and the better monthly maintenance is organized, the lower will be the consumption of lubricants for refilling and priming.

Detailed rules for lubricating contractor's machinery are contained in lubrication charts appended to the instruction book of each machine. Table 22 lists information on the lubrication of a number of machines.

FASTENING OF COMPONENTS

Components of detachable joints are fastened with bolts, screws, pins, studs, keys or cotters. These parts are called *fasteners.*

Table 22

Lubrication of Contractor's Machinery

Point of lubrication	Lubricant	Method of application	Frequency (hours of operation)
	Portable Belt Conveyors		
Take-up pulley bearings	Cup grease	Packing	200
Take-up screws	Ditto	Spatula	Before tensioning
Take-up guides	Ditto	Ditto	Ditto
Top idler bearings	Ditto	Packing	200
Bottom idler bearings	Ditto	Ditto	200
Drive mechanism intermediate shaft bearings	Ditto	Ditto	100
Drive pulley bearings	Ditto	Ditto	100
Drive mechanism gears	Ditto	Spatula	8
Bend pulley bearings	Ditto	Packing	200
Head pulley bearings	Ditto	Ditto	200
Winch gears	Ditto	Spatula	Before using
Wheel axle	Ditto	Ditto	Before traction
Roller axle	Ditto	Ditto	Ditto
	T-50 and T-52 Elevators		
Drive, intermediate and take-up shaft bearings	Cup grease	Spatula	200
Gears	Ditto	Ditto	8
	C-182A Jaw Crusher		
Swing jaw bearings	Cup grease	Grease cup	4
Tension rod loop	Industrial oil	Oil can	8
Main bearings	Cup grease	Grease cup	4

Table 22 (Cont'd)

Point of lubrication	Lubricant	Method of application	Frequency (hours of operation)
Tension rod spherical bearing	Industrial oil	Oil can	8
Adjusting block guides	Ditto	Ditto	8
Adjusting screw	Cup grease	Spatula	200
CM-11B, CM-166A and C-182B Jaw Crushers			
Swing jaw bearings	Industrial oil	Oil can	100
Joint between tension rod and swing jaw	Ditto	Ditto	8
Main bearings	Ditto	Ditto	100
Spring support	Ditto	Ditto	8
Adjusting block guides	Ditto	Ditto	50
Adjusting screw	Cup grease	Spatula	200
Standard Cone Crushers			
Countershaft bearings	Industrial oil	Continuous positive lubrication from oil sump	
Crushing head body, eccentric, and bevel gears	Ditto	Ditto	
Adjustment ring and rim	Cup grease	Pressure lubricator	100
Springs	Ditto	Spatula	As required
Motor bearings	Ditto	Packing	600
CM-12 Rolls			
Drive shaft	Industrial oil	Oil can	Replace oil every 1,000
Gears	Ditto	Ditto	Ditto
Roll bearings	Cup grease	Grease cups	400
Screws and springs	Ditto	Ditto	50
Movable bearing guides	Ditto	Spatula	50
Motor bearings	Ditto	Packing	600

Table 22 (Cont'd)

Point of lubrication	Lubricant	Method of application	Frequency (hours of operation)
	C-96 Eccentric Drive Screen		
Eccentric shaft bearings	Cup grease	Packing	200
Screen box bearings	Ditto	Ditto	200
Spring hangers	Ditto	Spatula	50

In the course of operation of the machine fastenings come loose, as a result of which one of the elements of a mated pair may lose its alignment with respect to the other.

The chief cause of fastenings coming loose is vibration of the parts during operation of the machine; besides, fastenings may come loose if the fasteners are of low quality or badly fitted to the mated components, or if the surfaces of the mated components are not of the right shape. This makes for faulty operation of the unit containing the elements in question and results in rapid wear and failure of parts. Hence, it is very important to tighten fasteners regularly, this job including: inspection of the fastenings, tightening and replacement of faulty fasteners.

The following signs are indications of unreliable fastenings; jingling of nuts when struck lightly with a hammer; rotation of nuts or screws when tried with a wrench or screw driver; vibration of mated parts during machine operation; displacement of components; leakage of gas, steam, water or oil through joint, and self-unscrewing of nuts.

There are several means of preventing nuts from coming loose: screwing on a second nut (called a lock nut) over the main one; insertion of a splint (Fig. 137*a*) above the nut, through the nut or in the grooves of a castellated nut; placement of check plates (Fig. 137*b*); use of spring washers (Fig. 137*c*); the hardened sharp edges of the oblique cut of this washer dig into the supporting surface resisting any tendency of the nut to come loose.

Nuts and bolts will not come loose of their own accord if they are properly threaded and the supporting surfaces of the nuts and bolt and screw heads are correctly positioned. Besides, care should be taken that the side faces of nuts,

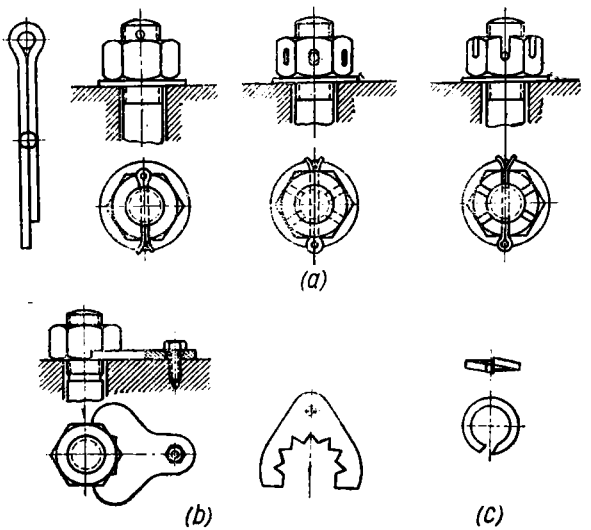


Fig. 137. Means of locking nuts:
(a) splint, (b) check plate, (c) spring washer

heads and screws are not injured (crumpled), or screw driver slots worn out. Studs and keys should be of the shape and size indicated in the working drawings and provided for by GOST; holes drilled for set screws must not be clogged or disfigured.

If inspection reveals bolts, studs, nuts or screws with incomplete, crumpled or torn threads they should be replaced; bolts, screws or nuts with injured heads or screw driver slots must also be removed.

The use of chance pieces of strip steel for washers is prohibited; washer contacting surfaces should be smooth.

Keys must not be crumpled or bent; they should be finished to fit tightly in their keyways.

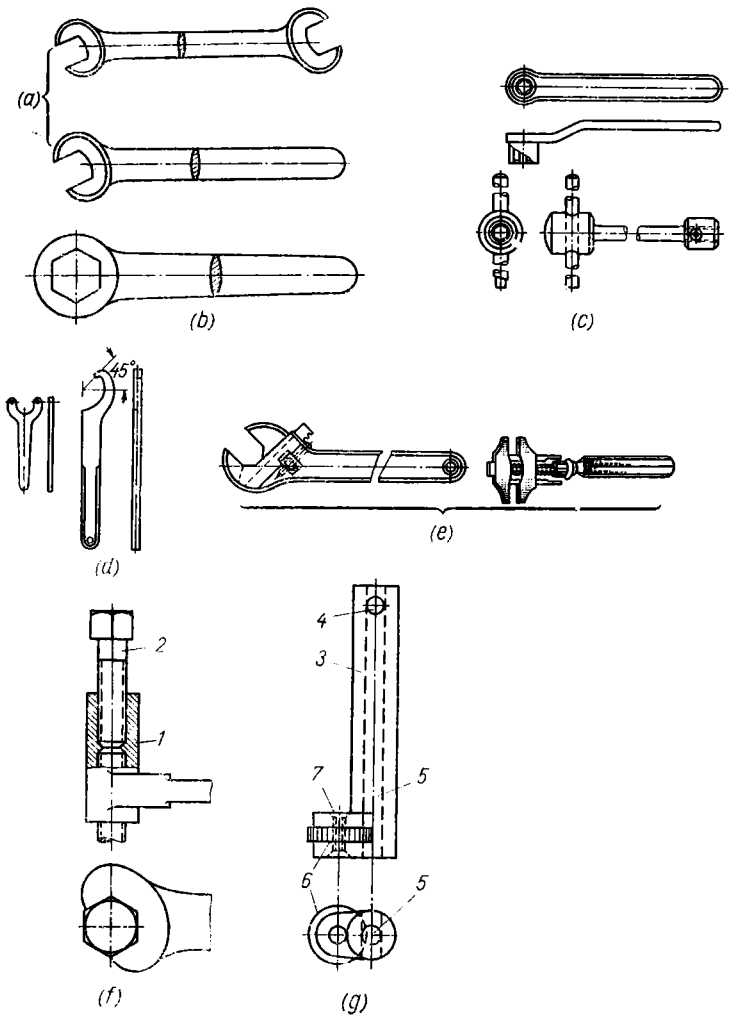


Fig. 138. **Wrenches:**

a) open-end wrench, (*b*) closed-end (box) wrench, (*c*) socket wrench, (*d*) spanner wrench, (*e*) adjustable, wrench, (*f*) stud wrench, (*g*) damaged stud wrench; *1*—nut, *2*—screw, *3*—body, *4*—hole, *5*—bore, *6*—disk, *7*—axle

It is good practice to replace faulty fasteners with new ones, repairing them only if there is no alternative.

Fastenings are tightened with the aid of wrenches and screw drivers.

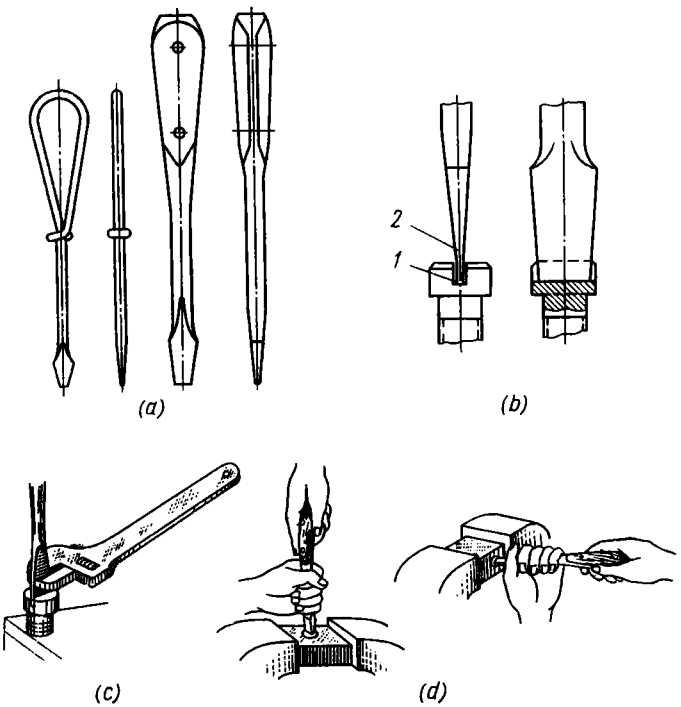


Fig. 139. Screw drivers:
(*a*) various types of screw drivers, (*b*) tip of a screw driver, (*c*) using a wrench to aid in unscrewing, (*d*) unscrewing in a vise; *1*—parallel faces, *2*—taper faces

Wrenches (Fig. 138) are used for screwing and unscrewing nuts and screws with faced heads (mainly hexagonal or square). The most convenient type are socket wrenches. Ordinary wrenches can be used for unscrewing nuts and screws of definite sizes, adjustable wrenches, for nuts and screws of a range of sizes.

Motorized wrenches, called speeder wrenches, are used to step up labour efficiency. These are socket wrenches rotated by a small motor built into the tool body.

A *stud wrench* is a thick nut *1* which is screwed on to the stud until the end of the latter stops against the end of a screw *2* which is then tightened slightly. Then the stud is screwed into its nest by rotating the nut with a wrench. When the stud is in place, the screw is loosened a little and the nut is unscrewed from the stud.

Damaged stud wrench has a bore *5* in its body *3*, by means of which it is slipped over the stud. To screw out the stud, the serrated disk *6* seated eccentrically on axle *7* is rotated until it contacts the stud; then a handle is passed through hole *4* and the wrench is rotated. The disk keeps the stud clamped while it is being unscrewed by rotating the wrench.

Screw drivers (Fig. 139) are used for tightening and loosening screws with slotted heads. The faces of the screw driver blade should be parallel over the entire depth of the slot.

MAINTENANCE OF RUBBER CONVEYOR BELTING

Conveyor belting should be stored in rolls or suspended from hooks. When rolling up the belt its surface should be sprinkled with talc, and the ends of the rolled belting should be coated with rubber cement to protect them from moisture and mould.

Belting must not be stored near heating units; the temperature in the store room should be 5-15°C and the room should be well ventilated. Belting must not be stored for more than six months because the rubber ages and loses its working properties.

Before installing the belting on the conveyor it is good practice to hold it for 24 hours under the atmospheric conditions (temperature, humidity) at which it is to operate.

To install belting first seat the roll on the axle of a trestle stand aligned with the conveyor axis; then draw the belting onto the conveyor by hand or winch, using a piece of rope tied to its end.

During operation the belt stretches greatly, and therefore, when installing it on the conveyor place the take-up

in the position wherein the distance between the head and tail pulleys is the smallest, to allow more travel for the take-up.

The service life of a rubber conveyor belt depends to a considerable extent on whether its ends have been joined properly for operation. If the ends are joined incorrectly the belt will perform unsatisfactorily and will run off the

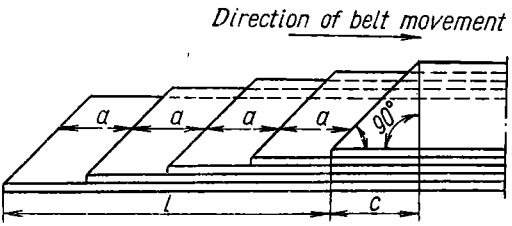


Fig. 140. Preparation of a stepped splice on an obliquely cut conveyor belt

pulleys. If the joint is too thick it will knock against the surfaces of the pulleys and idlers as it passes over them, causing excessive wear.

The ends of a conveyor belt may be lap-spliced or butt-joined.

To lap-splice a cotton rubber-coated belt cut its ends off at right angles to the side of the belt, and then at 30-45°. A 30° cut is used when the belting is thicker than 1/80 of the pulley diameter, and a 45° cut, if its thickness is equal to or less than this value. Cut steps on the ends according to the number of plies (Fig. 140). The step sizes for oblique cuts are listed in Table 23.

File the rubber down to the fabric on the step surfaces with a smooth-cut file and wash the fabric with gasoline. Cementing can be done directly after the gasoline has evaporated, using one part of No. 1 vulcanizing repair cement dissolved in four parts of gasoline.

Apply a thin uniform layer of the cement solution to the step with a brush, rubbing it into the fabric; allow the layer to dry until it no longer sticks to the fingers, then repeat this operation three or four times. Lay the steps successively on one another leaving a clearance of 1 mm

Table 23

Step Sizes for Obliquely Cut Belt Splices, mm

Belt width, mm	Length of step slant, mm		Number of plies							
			4		5		6		7	
	30° cut	45° cut	*i* *	*a* **	*i*	*a*	*i*	*a*	*i*	*a*
400	325	275	825	275	1,200	300	—	—	—	—
500	400	350	1,050	350	1,600	400	1,500	300	—	—
600	500	400	1,200	400	1,600	400	1,625	325	1,800	300
650	550	450	1,200	400	1,600	400	1,625	325	1,800	300
800	650	550	1,200	400	1,600	400	1,750	350	1,800	300
1,000	800	700	—	—	1,600	400	1,750	350	1,800	300

* *i*=splice length.
** *a*=step width.

between step butts for greater flexibility. The cemented step surfaces must fit snugly against one another; to achieve this roll them with a roller. Then compress the cemented joint between two plates heated to 100-120°C and hold it for 24 hours; if the plates are heated continuously (say, with electricity) the holding time may be reduced to 3 or 4 hours.

Without heating the ends may be cemented with No. 1 autovulcanizing repair cement. This cement consists of two parts, A and B, which are mixed in equal proportions before using (the mixture is good for 4 hours).

It is good practice to lace the joint with rawhide after drying.

Punch lacing holes 2.5-3 mm in diameter in the belt spaced at 35 to 50 mm. After lacing reinforce the splice with pitched thread.

Vulcanization of the splice after cementing gives a stronger joint. The conditions of vulcanization are listed in Table 24.

Butt joints are made with hinged or simple fasteners (Fig. 141).

The belts of conveyors operating in the open air should be covered with timber or canvas housings; the lumps of

Table 24

Vulcanization Conditions for Conveyor Belt Splices with Outside Strap

Number of plies in belt	Vulcanization temperature, °C	Vulcanization time, min
3	143	15-18
4	143	21-23
5	140	30
6	140	35
8	138	40
10	138	45
12	138	62

material fed to the conveyor must not be allowed to fall on to the belt. The use of special feed chutes is recommended to eliminate impact of the falling material against the belt.

The transported material should be distributed uniformly over the width of the belt, because if the load is one-sided, the belt may run out of train. It is bad practice to use side idlers to correct this fault, as they tend to wear out the belt edges.

The belt is trained during operation by using a crowned drive pulley, or troughing top idlers canted at 7-8° toward the head pulley. Faulty run-on at the head pulley can be corrected by skewing two or three of the idlers near the head pulley. The angle of skew of these idlers is sufficient as soon as the belt begins to run on to the pulley along the conveyor axis. If the belt runs off its idlers in the middle part it can also be trained by regulating the position of the idlers at the beginning of the part where the belt begins to run askew.

Belt tension must not be too great, as this may cause heating of the pulley bearings, bending of the shafts, untraining and rupture of the belt and excessive power consumption. During operation care should be taken to keep grease from falling on the belt, as this will cause stretching and separation of the plies. The latter defect may also be due to high ambient temperature or insufficient pulley diameter.

Rubber belts cannot operate at low temperatures (—30°C). At such temperatures they must be protected from moisture.

During operation the belt should be cleaned regularly to remove transported materials adhering to its surface;

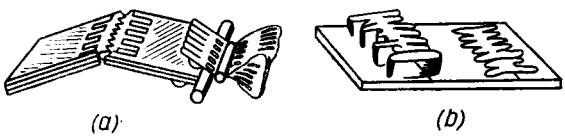


Fig. 141. Butt-joining a belt:
(*a*) with hinged steel fasteners, (*b*) with simple fasteners

spillage of the material on to the return side of the belt should be avoided. Regularly, every 50 hours of operation, the belt should be inspected and repaired or replaced if the least defects are detected.

Conveyor belting is repaired by hot vulcanization or autovulcanization.

Hot vulcanization is done as follows: cut out the injured spot with a wet knife; bevel the edges of the cut at 45°; brush with a steel brush; apply two or three layers of No. 1 cement, allowing each layer to dry before applying the next; cut out a patch from a sheet of unvulcanized repair rubber; bevel the patch edges at 45°; rub the edges of the patch and the cut with gasoline and allow the gasoline to evaporate; place the patch on the belt; roll the surface of the patch with a roller; level the patch off with a knife so that it does not protrude above the belt surface, and roll the patch edges once more with a roller.

Place the belt section containing the patch in a vulcanizing apparatus. The vulcanization temperature is 140-145°C and the vulcanization time, 15 min for patches up to 2 mm thick, 20 min up to 5 mm, and 25 min for patches thicker than 5 mm.

Autovulcanization (Fig. 142) is carried out as follows: cut out the injured spot; bevel and trim the edges; apply cement No. 1 in the same way as described above; cut out a patch from vulcanized repair rubber as above; prepare

a second patch of the same size as the first, from unvulcanized rubber; wet it on both sides with gasoline and apply two or three layers of autovulcanizing cement; place this patch on the vulcanized rubber one and roll. Apply two or

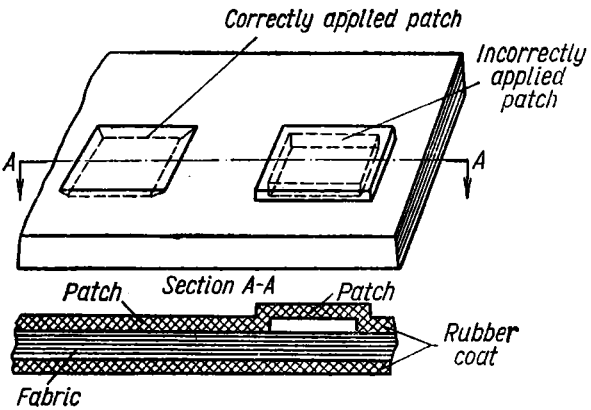


Fig. 142. Patching a conveyor belt

three layers of autovulcanizing cement to the unvulcanized side of the prepared patch, as described above. Place the patch unvulcanized side down on the belt, roll, even out, roll again and apply a weight of about 10 kg per square centimetre of patch surface area; hold the patch under the weight for up to 24 hours.

Minor local cover injuries are eliminated in the following manner. Cut out the injured part, trim, rub with gasoline, dry, fill in with autovulcanizing putty, even out the putty layer and hold under a weight for 4-5 hr.

If the plies have separated in a part of the belt, cut off the edge and cut out the cover, trim the parted plies, rub with gasoline, dry, insert spacers in the place where the plies have separated and repair in the same way as when patching.

To repair tears in the belt cut the rubber cover off both sides of the belt, trim, rub with gasoline, dry, apply a layer of cement, lace with cord and put a patch over the laced part, as described above.

If the belt is badly injured cut out the spoiled part and replace it with an intact piece of belting, joining its ends to the belt as indicated above.

MAINTENANCE OF FLEXIBLE DRIVES

Rubber Belting. The rules for storage of rubber transmission belting are about the same as for rubber conveyor belting.

Before installing on the machine rubber belting should be stretched; the stretching load for new rubber belting should be 30 to 40 kg/cm^2. Stretching should be repeated three or four times for 6 to 8 hours each time.

It is good practice before stretching to hold the belting for 24 hours under the condutions (temperature, humidity) at which it is to operate.

The ends of flat rubber belting are joined by cementing, vulcanizing, lacing, riveting, bolting, or with special fasteners. The best methods are the first two, because the splice obtained is of the same thickness as the belt, which makes operation smoother.

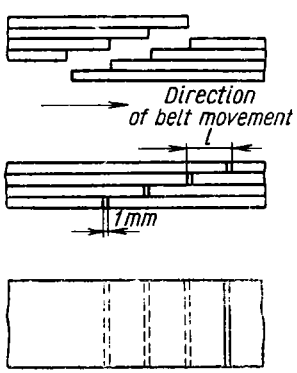


Fig. 143. Cemented stepped splice of rubber belt

Transmission belting is cemented and vulcanized in the same way as conveyor belting (Fig. 143). The length of the steps to be cut, depending on the belt width, is indicated in Table 25.

The number of steps should not be less than three and the butts should have a 1-mm clearance for better flexibility. At the working place cementing is carried out with the device illustrated in Fig. 144.

When installing a cemented belt take care that the stepped bevel of the belt runs on to the pulley as shown in Fig. 145.

Table 25

Step Length for Cementing Rubber Belting, mm

Belt width	Step length
up to 150	90
175-250	125
275-500	150
over 500	175

Lap lacing of a belt is illustrated in Fig. 146 and the dimensions for this type of splice are given in Table 26. Fig. 147 illustrates various methods of butt-lacing belts.

Table 26

Dimensions for Lacing Belt Ends

Item	Belt width, mm				
	80	100-150	175-250	300-350	400-500
Punch diameter, mm	4	5	6	7	9
Distance from edge of belt to first row of holes, *a*, mm	10	14	18	20	25
Hole spacing, *t*, mm	40	50	60	70	80
Rawhide strip width, mm	5	6	8	9	11
Number of rows	2	2	3	4	5

The lacings are tapped lightly with a wooden mallet so that they should not project above the surface of the belt.

Belt joints made with bolts and wire spiral lacing, and crest joints are shown in Fig. 148.

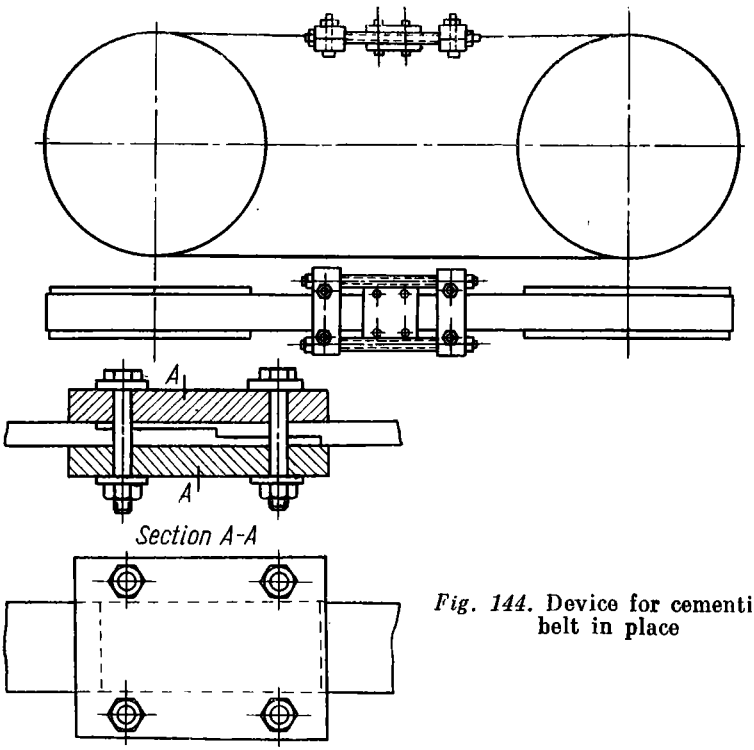


Fig. 144. Device for cementing belt in place

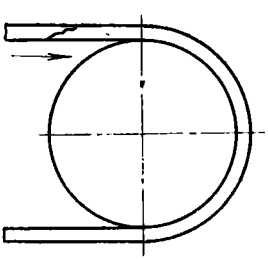


Fig. 145. Direction of bevel of belt running on to pulley

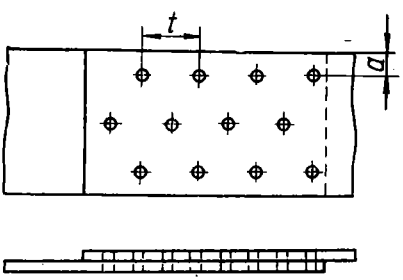


Fig. 146. Arrangement of holes for lap lacing a belt

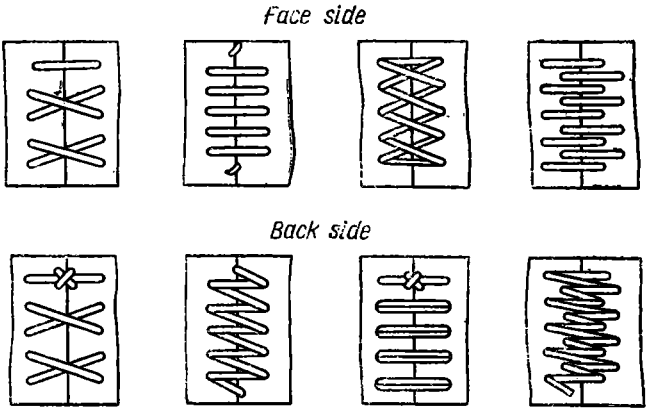


Fig. 147. Butt-lacing patterns

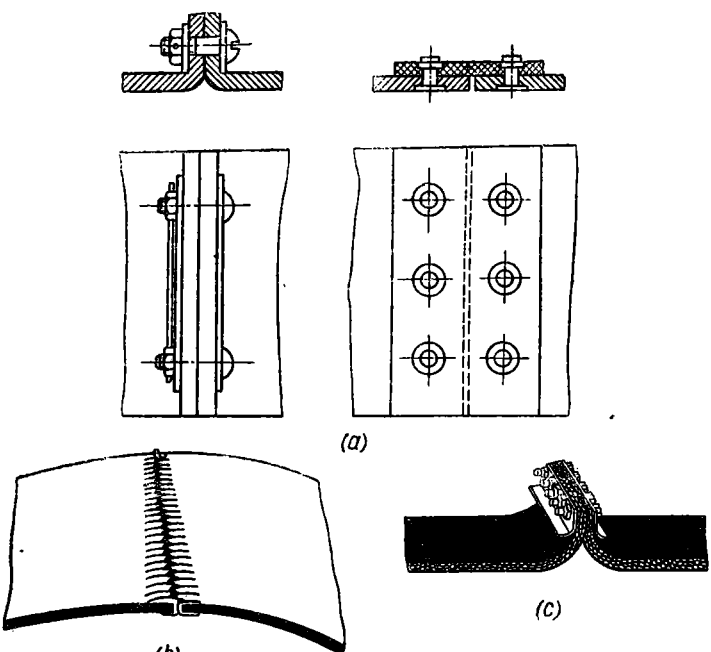


Fig. 148. Methods of joining belt ends:
(*a*) with bolts, (*b*) wire spiral lacing, (*c*) crest joint

The ends of a V-belt have to be joined when an endless belt gets torn or when the design of the machine makes it impossible to install an endless belt. In these cases the belt ends are joined by vulcanizing, with piano wire or metal fasteners.

A torn V-belt is vulcanized as follows: trim the belt, apply autovulcanizing paste to the injured surface, insert the belt in a hot mould and heat at 120-145°C for 15 min, remove from the mould, trim and dry at ordinary temperature for 24 hours. By vulcanization an intact piece of belting can be built into a torn belt in place of an injured part.

V-belts of O- and A-type cross sections may be laced with piano wire (Fig. 149); the ends of belts of B, Г or Д sections are joined with metal fasteners (Fig. 150).

During operation the tension of V-belts should normally be about 10 kg/cm^2.

For normal operation the belt should fit correctly into the pulley groove; Fig. 151 illustrates the right and wrong positions of the belt in the groove.

If a change of belts becomes necessary it is good practice to replace the entire set of V-belts of the drive so that all the belts should be of identical length and working qualities.

29. *Machine Repairs*

To repair a machine means to restore the shape, size and surface finish of worn elements or to replace them in order to completely restore the operating qualities of the machine. During repairs the nature of connections between components is also restored.

The most important jobs involved in repairs apart from maintenance work are partial or complete dismantling of the machine into units and the units into separate elements; machining of the worn parts to restore their shape and surface finish to new "repaired" dimensions; restoration of the original size of worn parts; replacement of worn parts or units; reassembly of units and the machine as a whole; adjustment of units, and testing and painting of the machine.

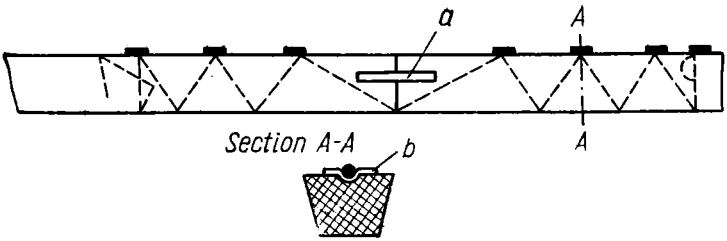


Fig. 149. Butt lacing of V-belt with piano wire:
(*a*) ring fastener, (*b*) rawhide lace pad

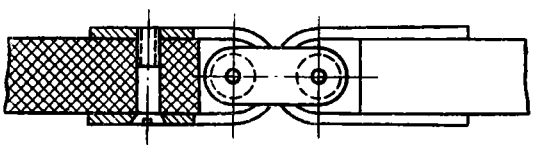


Fig. 150. Ends of V-belt joined with metal fastener

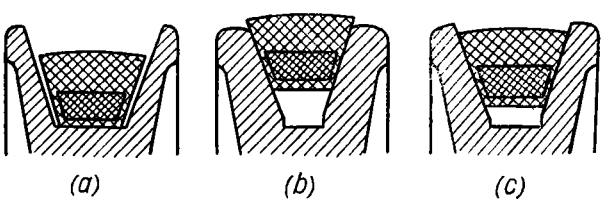


Fig. 151. Position of V-belt in pulley groove:
(*a*), (*b*) wrong, (*c*) right

Maintenance, operating repairs, partial and general overhauls should be carried out according to a predetermined schedule after every so many hours of operation of the machine, and should alternate in a given sequence, i.e., should be organized according to a definite system.

There are several systems of organizing repairs: one of the best is the preventive-maintenance overhaul system, abbreviated ППР (PMO), according to which the repairs of contractor's machinery are usually organized.

The PMO system is based on a plan according to which preventive (prophylactic) maintenance and repair measures are taken to apprehend rapid wear of machine elements and to make timely replacements of wornout parts. Owing to this, it is always known at the building site when, for how long and which machines are to be stopped down for repairs, and this makes it possible to carry on construction work without interruption.

The number of hours of operation of the machine from one scheduled repair to the next is called the *interrepair period.*

The number of hours of operation from one general overhaul to the next is known as the *repair cycle.* For new machines which have not yet undergone general overhaul the repair cycle is the number of hours of operation from start-up to the first general overhaul.

The PMO system involves compiling a plan beforehand for each machine covering all the kinds of repairs it is to undergo.

Fig. 152 is a schedule graph for conveyor repairs. According to this schedule the interrepair period is 1,200 hours of operation and the repair cycle, 4,800 hours; maintenance of one kind, operating repairs also of one kind, and a general overhaul are carried out in the course of a repair cycle.

Table 27 lists the frequency of recurrence of repairs, overhauls and maintenance for a number of machines.

The interrepair periods indicated are average values: at the construction site the length of the interrepair period is corrected depending on the conditions of operation.

Repair schedules form the basis for drawing up monthly and yearly repair plans indicating the number of individual kinds of repairs for different machines.

According to these plans the nomenclature and number of parts, amount of materials, man power, etc., needed for the repairs are determined on the basis of approved rates, as well as the amount of work to be done by the repair shops. The latter plan their work accordingly.

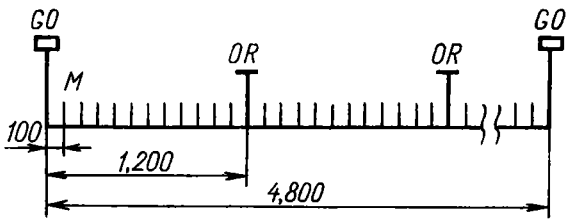


Fig. 152. Conveyor repair schedule

The following types of repairs are distinguished, depending on the technological complexity, labour consumption and time required to accomplish them: operating repairs, partial overhaul and general overhaul.

Operating Repairs. Operating repairs involve restoration or replacement of wornout parts whose lifetimes are equal or close to the interrepair period, or are multiples of this period, but shorter than one half of the repair cycle.

Hence, during operating repairs, the quickest-wearing parts are restored or replaced. Such are shafts, pins, axles, bushings, rollers, brake linings, gaskets, belts, oil cups, oil piping, damaged fastenings, etc.

This type of repairs also includes restoration of the connection between mated elements, unless this is too complex owing to the necessity of major dismantling, reassembly and other operations.

All these jobs require partial dismantling of separate units of the machine, such as sleeve bearings, friction mechanisms, etc.

Operating repairs are the basic type of repairs, because they eliminate the trouble as soon as it appears and prevent further quickly progressing wear of the machine.

Operating repairs should be done at the shortest possible intervals depending on the complexity of the machine. A set of spares should always be available near the machine

Table 27

Periodicity of Machine Maintenance, Repairs and Overhauls

Name of machine	Maintenance, operating repairs, partial or general overhaul	Frequency of recurrence, machine-hrs of operation	Man-hours required for repairs	Down time for repairs, calendar days
Vertical chain-and-bucket elevators, maximum lifting height 10 m	M	100	1	—
	OR	1,200	20	1
	GO	4,800	100	4
Ditto, maximum lifting height 18 m	M	100	2	—
	OR	1,200	30	2
	GO	4,800	120	4
Inclined chain-and-bucket elevators, maximim lifting height 10 m	M	100	2	—
	OR	1,200	30	2
	GO	4,800	140	5
Ditto, maximum lifting height 20 m	M	100	3	—
	OR	1,200	40	2
	GO	4,800	180	5
Vertical belt-and-bucket elevators, maximum lifting height 17 m	M	100	2	—
	OR	1,200	15	1
	GO	4,800	80	3
Ditto, maximum lifting height 27 m	M	100	3	—
	OR	1,200	20	1
	GO	4,800	90	4
Portable belt conveyors 5 m long	M	100	1	—
	OR	1,200	15	1
	GO	4,800	60	3
Ditto, 10 m long	M	100	2	—
	OR	1,200	18	1
	GO	4,800	80	3
Ditto, 15 m long	M	100	2	—
	OR	1,200	24	1
	GO	4,800	100	4
Sectional belt conveyors up to 40 m long	M	100	3	—
	OR	1,200	35	2
	GO	4,800	180	5
Ditto, 80 m long	M	100	4	—
	OR	1,200	40	2
	GO	4,800	200	6

Table 27 (Cont'd)

Name of machine	Maintenance, operating repairs, partial or general overhaul	Frequency of recurrence, machine-hrs of operation	Man-hours required for repairs	Down time for repairs, calendar days
Screw conveyors up to 8 m long, dia. 300-500 mm	M	200	2	—
	OR	1,200	25	1
	GO	4,800	75	3
Jaw crushers, gape 250× ×400 mm	M	100	2	—
	OR	1,200	20	2
	GO	7,200	120	4
Ditto, gape 250×900 mm	M	100	2	—
	OR	1,200	30	3
	GO	7,200	160	5
Rolls, capacity 30 m^3/hr	M	100	2	—
	OR	1,200	60	2
	GO	7,200	320	7
Cone crushers up to 2,100 mm dia.	M	400	5	1
	OR	1,200	100	3
	GO	7,200	500	8
Portable crushing plants, 10 t/hr capacity, with primary and secondary crushing	M	200	8	1
	OR	1,200	350	6
	GO	4,800	1,000	20
Portable crushing plants, internal combustion engine powered, capacity 10 t/hr	M	200	5	1
	OR	1,200	120	3
	PO	2,400	200	6
	GO	4,800	400	10
Portable primary crushing plants, internal combustion engine powered, capacity 30 t/hr	M	200	10	1
	OR	1,200	200	4
	PO	2,400	350	8
	GO	4,800	900	14
Ditto, secondary crushing, capacity 30 t/hr	M	200	10	1
	OR	1,200	300	6
	PO	2,400	400	10
	GO	4,800	1,100	18
Gravel washing trommels up to 20 m^3/hr capacity	M	400	7	1
	OR	2,400	42	2
	GO	4,800	90	4

Table 27 (Cont'd)

Name of machine	Maintenance, operating repairs, partial or general overhaul	Frequency of recurrence, machine-hrs of operation	Man-hours required for repairs	Down time for repairs, calendar days
Ditto, capacity from 21 to 45 m^3/hr	M	400	14	—
	OR	2,400	70	3
	GO	4,800	140	5
Unbalanced-throw screens, capacity from 13 to 30 m^3/hr	M	200	2	—
	OR	1,200	12	1
	GO	7,200	50	2
Ditto, capacity from 31 to 60 m^3/hr	M	200	2	—
	OR	1,200	24	1
	GO	7,200	40	4
Vibrating screens up to 20 m^3/hr capacity	M	200	2	—
	OR	1,200	12	1
	GO	7,200	50	2

to speed up operating repairs and replacement of quickly wearing parts. The parts to be included in this set are indicated in the operation instructions of each machine.

Operating repairs are done by the repair crew together with the machine operator under the supervision of a mechanic, without removing the machine from its working site.

Partial Overhauls. Partial overhauls involve the same jobs as operating repairs and restoration or replacement of worn parts whose lifetime is equal or close to half the repair cycle.

Partial overhauls also involve priming and replacement of bearings, machining and grinding of shafts, etc.

During partial overhauls machines are dismantled partly, but to a greater extent than during operating repairs.

General Overhauls. General overhauls involve the same jobs as partial overhauls and restoration or replacement of worn parts whose lifetimes are equal or close to the repair cycle.

Therefore, during general overhauls all worn parts, including those with the longest lifetimes, are restored or

replaced. These include heavy and large basic parts, such as frames, etc.

During general overhauls whole units (e.g., motors) of contractor's machines are usually replaced.

To carry out this work the machine has to be completely dismantled.

General overhauls involve the greatest amount of work and the most complex jobs.

Partial and general overhauls are carried out at repair shops where all the necessary equipment is available.

Acceptance of Machines for Repairs. Machines are shut down for repairs by order of the section mechanic in accordance with the corrected repair schedule.

Machines are handed over to repair shops for partial and general overhauls according to rules enforcing responsibility for the state of the machine and the quality of the repairs. Machines should be handed over for repairs only in complete sets, i.e., together with all parts, tools, implements and spares belonging to them.

The machine should be furnished with the following documents: technical certificate, operating instructions, repair log, description of the technical state of the machine, inventory of implements, parts and tools.

On arrival at the repair shop for partial or general overhaul, the machine is cleaned, washed and inspected to establish its state and whether any parts, tools or documents are missing.

After inspection the machine is dismantled.

The removed parts are freed from dirt and remains of grease and then are inspected and measured to establish how greatly they are worn or injured, these data being put down in a check list. The latter is the basis for determining the volume and cost of the work to be done during the partial or general overhaul.

Returning and Acceptance of Machines After Repairs. After repairs machines should be accepted under load; if this is impossible the repaired machine may be accepted in idle operation. But all machines having braking and friction mechanisms must be accepted only under load.

All repair defects noticed must be eliminated immediately.

When accepting machines returned after repairs a special acceptance affidavit should be drawn up and signed.

Unit Repair Method. The unit method of repair of contractor's machinery has been practised more and more extensively in recent years. According to this method separate defective assemblies are removed from the machine and replaced by previously repaired or new ones.

The unit repair method reduces down time of the machine for repairs by 40 to 50 per cent.

30. Dismantling and Reassembling Machines

Tools for Dismantling and Reassembling Machines. A number of tools are used for dismantling and reassembling movable and stationary connections. Besides the wrenches and screw drivers described above, these include the following tools.

Drifts are used when disassembling machines, for dislodging pins from their holes in mated parts.

Knock-outs are used for dismantling an assembly the components of which are mated by close fits. The knock-out is made of a softer material than that of the parts to be separated. To use the knock-out place it against the end of the component being removed from the hole in its mate and strike it with a hammer to knock the component out.

The *puller* (Fig. 153) is another of the tools used for disconnecting components mated by a close fit.

Parts are disconnected with a screw-type puller as follows: one of the parts is engaged by the claws, while the screw of the puller is pressed against the other.

Other instruments needed for dismantling and reassembling machines, besides those mentioned above, are: a set of measuring instruments and fitter's tools, surface plates and special devices for checking the alignment of elements and units when putting them together.

Screw, *rack-and-pinion*, and *hydraulic presses* are used for pressing parts on to one another when making close fits. Special screw-type devices may also be used for this purpose.

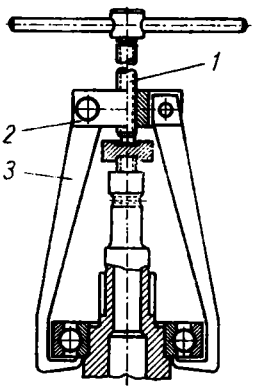


Fig. 153. Screw-type puller:
1—screw, *2*—cross piece, *3*—claws

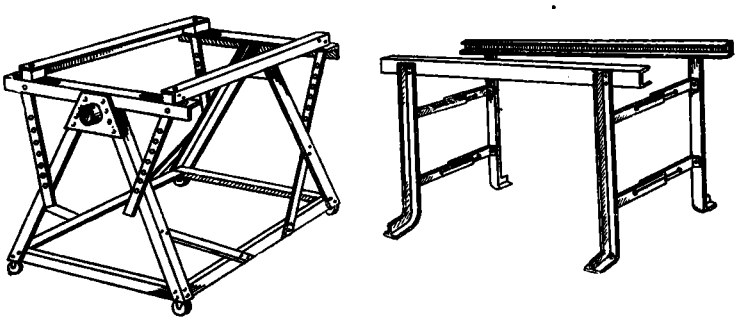


Fig. 154. Simple types of stands

Benches or *stands* (Fig. 154) are needed to support units during dismantling and reassembly.

The following hoisting equipment is most commonly used for lifting machine elements during disassembly and reassembly: jacks, worm-gear hoists, trolleys, castor-mounted stands, tripods, cantilever cranes, overhead cranes and other equipment, depending on the size and weight of the parts.

The *screw jack* (Fig. 155*a*) is usually set under the part or assembly. When screw *1* is screwed out of the nut inside the jack body, the head *2* which rotates freely on the screw thrusts against the surface of the load and lifts it. The screw is rotated by means of handle *3*. When the latter is turned the pawl *4* seated on an axle between the cheeks of the handle engages the teeth of a ratchet keyed to the screw, rotating it so as to screw it out of the nut in the jack body.

The *rack-operated jack* (Fig. 155*b*) consists of a steel or wooden body *8* enclosing a toothed rack *6*. The latter has a free-rotating head *5* at the top which thrusts against the load; the bottom end of the rack has a platform (flange) *10* by means of which the rack can engage a surface situated in the lower part of the load.

On being moved out, the head or abutment of the rack thrusts against the load and lifts it. The rack is actuated through gears by rotating lever *9* which is furnished with a brake. The ratchet *11* keyed to the drive pinion shaft and the pawl *7* seated on an axle fixed in the jack body serve to fix the load in its raised position.

The *worm-gear hoist* (Fig. 155*c*) is suspended from special beams, trestles or tripods by means of hook *12*. The hook is fastened to steel cheek plates through which the axle *13* is passed. This carries a chain sprocket *14* made integral with the worm wheel *15*. The worm wheel and sprocket are rotated by a worm *21* which in its turn is rotated by a pocket sheave *16* seated on the end of the worm shaft. Sheave *16* is rotated by pulling the operating chain *17*.

The other end of the worm shaft has a braking device. The load chain *20* passes over sprocket *14* and around the sheave *19* having a hook *18* attached to its fork, on which the load is hung. One end of chain *20* is fixed between the

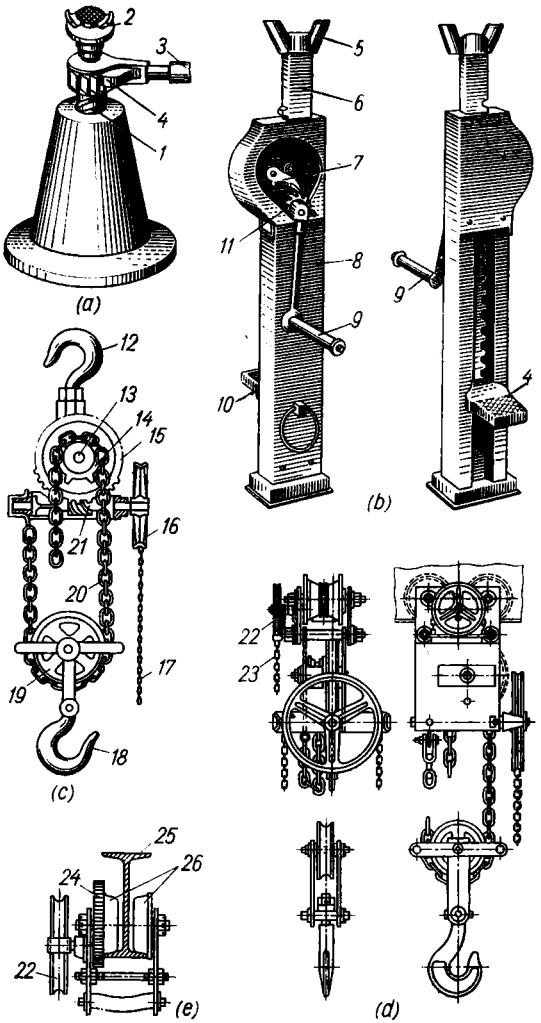


Fig. 155. Hoisting equipment for dismantling and assembling machines:

(*a*) screw jack, (*b*) rack-operated jack, (*c*) worm-gear hoist, (*d*) hand-powered trolley, (*e*) trolley travel mechanism; *1*—screw, *2*, *5*—heads, *3*—handle, *4*, *7*—pawls, *6*—rack, *8*—body, *9*—lever, *10*—platform (flange), *11*—ratchet, *12*, *18*—hooks, *13*—axle, *14*—sprocket, *15*—worm wheel, *16*, *22*—pocket sheaves, *17*, *20*, *23*—chains, *19*—sheave, *21*—worm, *24*—gears, *25*—beam, *26*—roller,

cheeks of the hoist, and the other hangs down from the sprocket.

The lifting capacities of worm-gear hoists range from 0.5 to 5 tons.

In some cases the hoist is suspended from a beam (Fig. 155*d*, *e*) by the tension of an operating chain *23* with the aid of a pocket sheave *22*, gears *24*, and rollers *26*. The hoist can be moved along the beam *25*. This mechanism is known as a hand-powered trolley. With its aid the load can be lifted and moved horizontally along the beam.

Electrically or internal-combustion-engine powered *overhead cranes* and *trolleys*, *narrow-gauge trucks*, etc., are used for carrying machine parts and assemblies. Large members and units can be moved over small distances by means of steel pipes used as rollers, which are placed under the part.

Slings and *tongs* (*catches*), shown in Fig. 156, are used for fastening the load to the hoist hook when lifting it. Fig. 156*a* shows different kinds of slings. A ring is attached to one end of a length of rope and a hook to the other. The ring is put on the hoist hook, and the load is gripped by the sling hooks. Scissor-type and hook catches are illustrated in Fig. 156*b*.

Methods of tying ropes when lifting loads are shown in Fig. 156*c*.

Disassembly and Reassembly Techniques. Before disassembling all parts of the machine should be put in a position precluding the possibility of their shifting downwards or falling, i.e., moving by gravity, the tension of a spring, etc. For this purpose disconnect the machine from its motors by removing drive belts and chains and/or disconnecting its couplings. Then clean off any grit, residual lubricant, soil and building materials.

Machines should be disassembled in a definite order, starting by removing individual units which might interfere with dismantling of other units, or such as must not be left on the machine upon further disassembly according to safety rules.

Disassembly is usually begun by removing the basket, the cabin, the guards, and then separate large units, the winch, motor, etc. Then the units of the machine connected

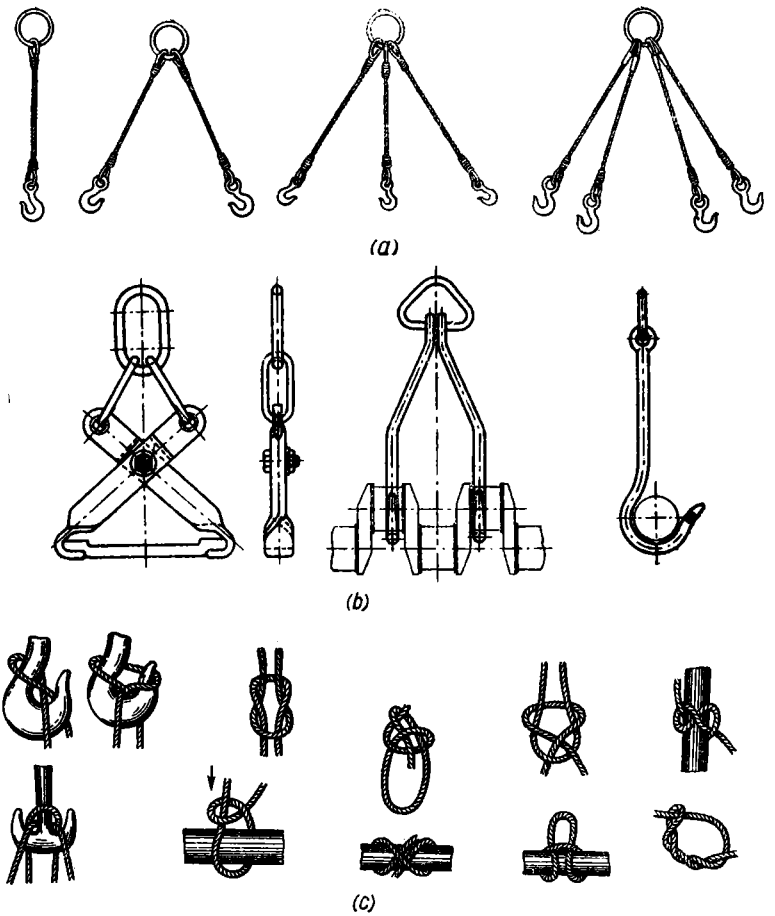


Fig. 156. Devices for gripping loads when hoisting, and methods of fastening:
(*a*) rope slings, (*b*) catches, (*c*) knots for ropes

by couplings are uncoupled and the drives and transmissions are taken apart.

A definite order of disassembly of the machine is decided upon depending on its construction.

Units removed from the machine are set on stands, benches or pads and are taken apart.

The order of dismantling units is the same, i.e., first of all those sets must be removed which otherwise block other components or make it impossible to disassemble them.

During disassembly of machines the parts should be marked. This is necessary in order to leave no doubt during reassembly as to which machine and unit each part belongs.

Besides, when dismantling some units a mark should be made to indicate the mutual position of mated components, e.g., gears. In such cases make the marks (for instance, by centre punching) so that the mark on one of the components is opposite that on the one mated with it. The position of these marks can then be taken into account when remating the components.

After disassembly collect all small parts (bolts, screws, small shafts, etc.) into a box. Lay the larger members (shafts, pulleys, gears, etc.) on special shelves or stands. Set very large and heavy members (frames, steel structures, etc.) on blocks or mats at the place of disassembly.

Before inspecting and repairing clean off dirt, remains of grease and other contaminants; this is best done by washing in kerosene or, in the case of small and medium-sized parts, by boiling in a bath (special vat) with a ten per cent solution of caustic soda. After washing and drying, inspect and measure the parts. All parts which are unsuitable for further use should be rejected and scrapped. Members which can be repaired are sent to a special store room and thence to the repair shop; members that are still in good shape are sent to the store room, from which they are remitted when the machine is to be reassembled.

Disassembly of machines and units involves disconnection of bolt, stud, splice, key, and cottered joints and close fits.

When disconnecting bolt and stud joints first determine whether the thread is right- or left-handed, and then

unscrew the nut using a wrench of normal length. The use of wrenches with extended handles is bad practice, because they are liable to damage the thread or rupture the bolt.

If the nut will not come off use one of the following methods: screw the nut a little tighter, then loosen it; pour a little kerosene between the bolt and nut threads, wait a few moments for it to sink in, and then loosen the nut; tap the nut flats lightly and rapidly with a hammer, and then unscrew.

Screw joints are disconnected with a screw driver. If the screw will not come loose pour a little kerosene under its head and then unscrew, pressing the screw driver tightly into the slot and turning it with a wrench.

When disconnecting stud joints drive the stud out with a knockout rod. The diameter of the operating end of the latter should be a little smaller than the stud diameter.

Taper keys are dislodged with a square-ended knockout rod a little smaller in cross section than the keyway.

Parts spliced to shafts or keyed to them with prismatic keys are removed by hand, with strippers, or with a knockout rod if the shaft is a short one or the part is seated on its end.

Components of close fits are separated with the aid of strippers or knockout rods. If the interference is large, the component seated on the shaft is heated and then removed with a stripper or the male component is pressed out.

Reassembly of a machine consists of the following chief operations: cleaning of the members before assembly, lapin of mating components, assembly of parts into units, check-up of relative position of components, balancing of parts rotating at high speeds, setting up of frames or main frames, putting separate members and units in place on the frame or main frame, alignment of mated components of separate units, and testing of mechanisms. All sharp edges and burrs should be trimmed off parts before they are assembled and metal filings, chippings and lubricant should be removed from their surfaces.

The order of reassembly of elements into units and units into machines is approximately the reverse of the order of disassembly of the machine.

Before being put together into units the parts of contractor's machines should be lapped in by adequate bench oper-

ations. The unit should be put together starting from a definite part known as the *base*.

The flow pattern of assemblying parts into units and units into machines provides for a definite order of assembly operations.

The reconditioned or newly made parts received by the repair shops to assemble into machines must be trimmed and washed again before assembly. After washing they are wiped with cotton waste. Parts to be riveted or bolted together should be coated with a thin film of grease to keep them from corroding.

If the machine was completely disassembled for repairs its assembly consists of the following operations: setting up frames and main frames; assembly and balancing of stationary, moving, rotating and transmitting components.

The sequence of assembly operations is: bench lap-in of parts, putting together of units, setting members and units in place on machine frame or main frame.

If the machine was only partly dismantled, the procedure will consist only of assembling one or several units and putting them in place on the machine frame or main frame. Thus, assembly of any machine can be broken down into the putting together of individual units.

Assembly Procedure for Chief Units of Contractor's Machines. The procedure of assembling a unit depends on the nature of the unit.

Before assemblying machine *main frames* or *frames* should be cleaned and set up firmly, taking care to keep the individual members level or strictly vertical, as necessary. The frame or main frame is levelled lengthwise and transversely using a straight-edge and level; the straight-edge should be longer than the length to be checked whenever possible. Erectness should be checked with a plumb line. The correct position is attained by driving wedges under the frame and replacing them by steel pads after it is found and checked.

Before installing *shafts* and *axles* in their bearings they should be cleaned and wiped, sharp edges should be removed from the shafts and bearings and all damaged spots on the rubbing surfaces should be ground down. Plain bearings should have lubricating grooves milled on them; lubricat-

ing holes in the bearings and shafts (when the lubricant is fed through the journal) should be cleaned out.

Bushings should be pressed in place and made fast with set screws, then reamed and scraped to fit the shaft, if necessary.

Before installing shafts and axles in their bearings make sure their centre lines coincide with those of the bearings. The centre lines of the bearings in which the shaft or axle is installed must be strictly aligned; to check this place disks with holes in their centres in the two end bearings and draw a string through the holes. If the shaft is supported by more than two bearings place wooden half-cylinders in all the rest of them, having grooves along their centre lines. If the bearings are installed correctly, the taut string will lie snugly in the grooves.

To check horizontal alignment of the centres set a straightedge on the inside surfaces of the lower half-inserts and place a level on it. It is good practice to adjust bearings of contractor's machinery vertically within one millimetre using steel shims from 0.05 to 0.5 mm thick; before the bearing covers can be tightened down the shaft centres must lie not more than 0.3-0.4 mm above the position indicated in the drawing.

Before installing the shaft in its bearings slip on all the solid parts that should be on it according to the design, such as gears, pulleys, clutches, thrust rings, etc., which cannot be put on after the shaft is in its bearings. Then place the shaft in the checked bearings and check it at several points with a level. If the shaft is found not to be quite level, make it so by inserting shims under the bearings. When assembling shafts in bearings the nature of the fit should be retained.

When installing shafts in ball bearings the housings of the latter should be aligned with a string. Before installing, the bearings should be flushed and greased, and oil-soaked felt rings should be inserted in the housing grooves.

Set the shaft with its bearings in the lower halves of the bearing housings. The bearing rings should fit freely in the housing grooves, as an axial clearance between the rings and housing is necessary to allow for slight axial movement of the shaft.

When installing shafts which are afterwards to be connected with couplings check to see that their axes are aligned, and when they are to be connected by a gear, chain or belt drive, that they are strictly parallel or perpendicular, as required, and that the distance between them is exactly in accordance with the design.

There are two ways of checking shaft alignment. In one of them a yoke with a screw (Fig. 157*a*) is slipped over the end of one of the shafts. Set the tapered end of the screw 0.3 to 0.4 mm above the surface of the shaft and fix it in place with a lock nut. Mark the position of the screw on the shaft with a pencil. Then rotate the shaft; if the shafts are aligned correctly the distance between the tip of the screw and the surface of the shaft should be the same for all positions of the shaft. Measure this distance with a clearance gauge; if more exact measurements are required make them with a special instrument called an indicator.

In the second method yokes with pointers (Fig. 157*b*) are fastened to the ends of the shafts. Set the tips of the pointers 0.3 to 0.4 mm apart, measuring the distance with a clearance gauge. If the shafts are well aligned this distance should be the same in all positions of the shafts when they are rotated.

After checking the shafts may be coupled. If the shafts are to be connected by disk couplings slip the disks over the shaft ends before the shafts are installed in their bearings; the bolt holes in the disks should coincide.

If the shafts are to be connected with claw clutches key one half-clutch to the end of one shaft and the other half-clutch to the end of the other, and then install both shafts in their bearings.

Adjust the clearance between the centres by shifting the bearings; for this purpose the holes for the housing bolts in the bearing base plate are elongated.

Shafts and axles are checked for parallel alignment with inside caliper gauges and beam calipers or by one of the following methods.

If the shafts carry pulleys or sprockets a plumb line is let down at one side of the pulleys or sprockets as close to the shaft as possible (Fig. 158).

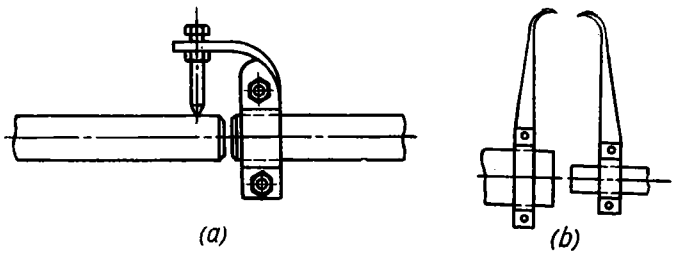


Fig. 157. Devices for checking alignment of shafts before coupling:
(*a*) yoke with screw, (*b*) yokes with pointers

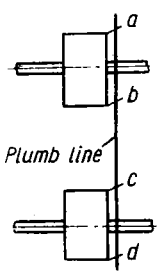


Fig. 158. Checking parallel alignment of shafts with a plumb line

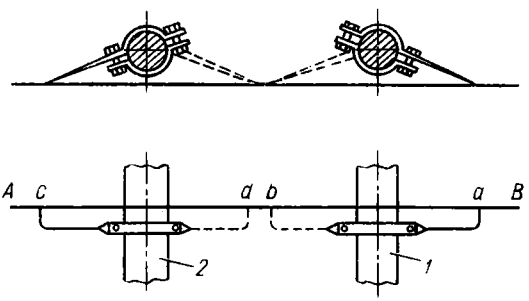


Fig. 159. Checking parallel alignment of shafts with pointers:
1, *2*—shafts

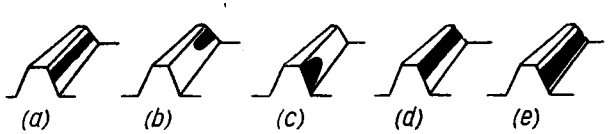


Fig. 160. Paint contact patterns on teeth of driven gear:
(*a*) right, (*b*), (*c*) wrong (shafts skewed), (*d*), (*e*) wrong (excessive and insufficient clearance, respectively)

If on being brought slowly closer to the rim the line touches the pulleys at points *a*, *b*, *c*, and *d*, the shafts are parallel. If only one of the shafts carries a pulley or sprocket, a set square placed on the second shaft can be used instead of the other pulley or sprocket; in this case the line should be parallel to the rim of the pulley or sprocket and to the vertical side of the set square.

Parallel alignment of shafts can also be checked by means of pointers clamped to the shafts (Fig. 159). Stretch a string between two stands or supports so that the pointer on shaft *1* touches it at *a*, and then at *b* when the shaft is turned a half revolution; then bring the pointer of shaft *2* up to the line so that it touches it at *c*, and again at *d* when the shaft is turned a half revolution; if this condition is observed the shafts are parallel.

Perpendicular shaft alignment is checked with a set square. The permissible deviations from the specified clearance between centres, parallel, horizontal or perpendicular alignment for installed shafts of belt, chain, gear, and worm drives are indicated in the list of specifications for assembly of the machine in question.

When assembling a *spur gear drive* the distance between centres should be equal to half the sum of the pitch diameters of the engaging gears.

If the clearance between gear centres is correct they should touch at their pitch circles when rotating; observance of this condition will ensure that the radial clearance between the teeth is correct.

Before seating pulleys or gears on shafts, and before assembling belt or gear drives, always check the surfaces of the inserts and journals; gears and pulleys should be freed from remains of metal chips and grit. Before being seated on shafts pulleys and gears should be balanced.

Solid pulleys and gears are forced on with a press or by hand with a hammer, using a copper or wooden pad.

To seat a pulley or gear on a short shaft set the latter upright, place the part on it and drive it on by tapping the hub with a hammer alternately at diametrically opposite points. Take care not to skew the component being driven on. Avoid large stresses when driving the parts on, as they are liable to break the hubs of cast-iron pulleys or gears.

When the gears are seated properly on the shafts they should be checked to see that they do not wobble axially or radially, using chalk, a surface gauge or an indicator, depending on the required precision of assembly.

The radial and axial play of machined gears after they are seated on their shafts depends on the speed of rotation and diameter of the gears; it must not exceed the limit value indicated in the assembly specifications.

The clearance between the teeth of new machined gears should be within the limits specified in the technical data.

To check the clearance between teeth use a thickness gauge or insert a lead plate or wire between them and then measure the thickness of the impression with a micrometer gauge.

If the clearance is larger than specified, the gear teeth thickness is smaller than the permissible limit value, or the distance between the shaft centres is too large.

Gear engagement is checked with marking compound (Fig. 160). A thin film of paint of the same kind as is used for scraping is applied to the surface of the drive gear teeth. When the gears are rotated this film will leave contact pattern over the face width of the driven gear tooth. If the engagement is correct the contact pattern may be continuous or interrupted, but its length should total not less than 70 per cent of the face width. The distance from the outside edge of the tooth to the contact pattern may be between 0.5 and 2 mm. If the contact pattern does not cover the entire face width, but is only at alternate corners, the shafts are skewed vertically. If the contact pattern covers only one end of the tooth, the shaft centre lines are not parallel. With such assembly defects only part of the tooth surface is working; this increases tooth wear and may result in breakage.

If the shafts are aligned strictly parallel and the gears are correctly made any inaccuracies in engagement of their teeth can be eliminated by adjusting the positions of the gears.

If the contact pattern on the working and nonworking surfaces is too close to the thin part of the tooth the engagement is adjusted by moving the driven gear back; if the design of the connection includes spacing shims the latter should be transferred from the left-hand to the right-hand

side; at the same time the position of the drive gear should also be adjusted by changing the number of spacing shims.

If the contact pattern on the surface (working and non-working) is too close to the thick part of the tooth the driven gear should be moved up.

When the contact pattern is too high the drive gear should be moved up and the driven one moved back. When the contact pattern is too low the drive gear should be moved back and the driven one up.

After the right contact pattern has been obtained check the clearance.

If spur gears are found to be wobbly check to see whether they are seated properly on the shaft and whether the bushing is positioned correctly in the hub.

The shafts of spur gears that have been checked for wobbling, can be checked for parallel alignment by placing a rule against the butt of one of the gears. If the shafts are parallel the rule will lie flat against the butt of the other gear as well.

When assembling *bevel gear drives* the two shafts must intersect at 90°. The permissible deviations for various bevel gear drives are indicated in the machine repair specifications.

In the case of gear drives requiring high precision the gears are burnished or worked in with or without abrasives. Burnishing is sometimes done with a steel master gear with hardened teeth against which the teeth of the cast gear are worked in. This operation is usually performed on special machines.

31. Machine Operation Troubles

Machine operation troubles may be due to wear-out of elements, distortion of their mutual position, faulty manufacture and assembly, and breaches of operation rules.

Tables 28-33 list the principal kinds of trouble encountered in the operation of conveying, crushing and sizing machinery, and methods of remedying it.

Table 28

Typical Troubles in Principal Machine Units and Their Remedies

Trouble	Cause	Remedy
	Bearings	
Abnormal heating	Insufficient grease	Add grease
	Wrong type of grease	Select grease in accordance with instructions
	Grease and bearing contaminated	Remove grease, flush bearing with kerosene and refill with fresh grease
	Leakage of grease due to excessive clearance in sleeve bearings and wear-out of packing in roller and ball bearings	Adjust clearance by removing shims or by repairing bearing; replace packing
	Excessive tension of flexible component (conveyor belt, drive belt, drive chain)	Adjust tension by shifting motor or with the aid of the take-up of the flexible component
	Scoring of the journal surfaces in sleeve bearings	Disassemble, flush with kerosene, dress surface, reassemble and fill with fresh grease
	Worndown bearing	Replace bearing
	Faulty assembly	Check position of shaft and bearings; cover fastenings of sleeve bearing; assembly of roller and ball bearing
Excessive wear	Faulty lubrication	Change grease
	Excessive tension of flexible component, faulty assembly	Adjust tension by shifting motor

Table 28 (Cont'd)

Trouble	Cause	Remedy
	Idlers, Pulleys, Sheaves	
Reduced speed or no rotation	Faulty bearings	Replace bearing
	Seizure on axles with sleeve bearings	Check position of axles, eliminate seizure
	Drag of material or foreign matter	Clean out, remove foreign matter
	Excessive tension of flexible component	Adjust tension

Table 29

Belt Conveyor Troubles and Their Remedies

Trouble	Cause	Remedy
Belt out of train	Drive or take-up pulley shafts skewed	Check position of pulley bearings, eliminate skew
	Faulty position of idlers	Set idlers at right angles to conveyor centre line
	Faulty lacing of belt	Relace belt and adjust tension
	Build-up of material on pulleys and idlers	Clean pulleys and idlers, adjust scraper
	Feed falling on one side of belt	Correct faulty feeding
Belt shifts alternately to left and right	Conveyor has transverse slope	Level out conveyor
	Excessive belt tension	Adjust tension
Belt sags badly between idlers and slips on drive pulley	Insufficient belt tension	Take up slack, relace if necessary

Table 29 (Cont'd)

Trouble	Cause	Remedy
Considerable spillage of material at feed hopper	Rubber strips on bottom edge of hopper worn out	Replace strips
	Conveyor grade too large	Reduce grade
Slippage of pay load	Feed hopper skirtboards rubbing against belt	Reinstall skirtboards properly
Working surface of belt damaged	Pieces of material caught between belt and feed hopper skirtboards	Close clearance between belt and skirtboards with rubber strips
Belt edges damaged	Belt edges rubbing against stationary parts of conveyor owing to belt being out of train	Train belt
Guide rollers do not move along axles	Faulty assembly	Check position of axles, rollers, pulleys
	Seizure on axles	Ditto
Abnormally noisy drive	Insufficient lubricant or absence of same	Add or prime with lubricant
	Improper or poor-quality lubricant	Remove and replace with good-quality lubricant
	Wornout or broken teeth	Replace gears
	Faulty assembly	Check engagement, correct faults
Housings of closed gearings (reducers) get hot	Ditto	Ditto
Inhibited operation	Ditto	Correct faulty assembly

Table 30

Bucket Elevator Troubles and Their Remedies

Trouble	Cause	Remedy
Buckets knock against casing walls. Belt runs off pulleys or skids on drive pulley	Belt or chain has become slack	Take up slack
	Pulleys skewed	Eliminate skew
	Faulty lacing of belt	Check lacing and relace if necessary
	Material comes between belt and pulley	Feed material uniformly, avoid clogging boot
Abnormal stretching and wear of belt	Excessive strain on belt due to high resistance when digging into material with clogged boot	Eliminate clogging of boot
Rapid wear of chain hinges	Flapping of chains owing to slack	Take up slack
Spillage of material in return casing	Faulty setting or wear-out of discharge plate at elevator head	Adjust position of plate or replace if worn out
Knocking in casings	Faulty assembly of casings	Check to see that casings are strictly vertical, eliminate breaks at casing junctions
	Bucket fastening broken	Inspect bucket fastenings and replace broken ones

Table 31

Crusher Troubles and Their Remedies

Trouble	Cause	Remedy
	Jaw Breakers	
Crushing stops	Toggle broken or rivets holding toggle together sheared	Replace or rivet toggle
Knocking in lower part of crusher	Spring loose or broken	Replace spring
Spring keeps breaking	Spring excessively compressed	Relieve spring
	Spring not relieved after decreasing setting	Ditto
Tension rod keeps breaking	Ditto	Ditto
Excessive amount of oversize in crushed product	Lower parts of jaw plates worn out	Reverse jaw plates or adjust discharge opening; replace jaw plates
Vibration of jaw plates	Plate fastenings have come loose	Loosen nuts; using sledge hammer and wooden block, drive cheek plates down as far as they will go, then retighten nuts
	Standard Cone Crushers	
Oil stoppage in piping	Insufficient grade of oil drain pipe	Increase grade of oil drain pipe
Adjustment ring hops on springs	Excessively high feed rate or slack springs	Adjust feed rate or tighten springs
Low rpm	Belt slack	Check motor fastenings, relace belt
Excessive amount of oversize in crushed product	Mantle worn down	Lower bowl

Table 31 (Cont'd)

Trouble	Cause	Remedy
Crushing head and feed plate remain motionless while pulley rotates	Bevel gear or pinion key sheared	Replace key
Drive pulley rotates irregularly, knocking	Broken teeth on bevel gear	Replace gear
Bolt falls out of nest in main frame and spring	Main frame tie bolt broken	Replace bolt
Vibration of crusher with material of normal moisture content	Springs gone slack	Tighten or replace springs
No oil jet in oil motor, excessive heating	Oil pump stopped working	Find point of excessive heating, dismantle pump; check piping to and from oil reservoir, clean out pump and piping and reassemble
Excessive noise during operation, lining comes loose	Bolt, stirrup or bowl liner spring strip broken	Remove rim, replace bolt or stirrup and spring; simultaneously inspect protector and bowl liner fastenings
	Rolls	
Crushed product too coarse	Clearance between rolls has changed	Insert shims between thrust block and bearing housing
	Movable roll spring has come slack	Tighten spring
	Roll shells worn out	Replace or repair shells

Table 31 (Cont'd)

Trouble	Cause	Remedy
Roll shells worn down at edges	Separating angle (of deflector) has not been removed	Remove angle
Reduced rpm	Belts have come slack	Take up slack
Shearing of split safety rings	Uncrushable material of a size greater than the movable roll travel has fallen in	Replace rings
	Hammer Mills	
Abnormal vibration during start-up	Rotor improperly balanced	Clean out grate, remove hammers and weigh them. Select properly balanced hammers and reinstall them
Knocking in the mill	Uncrushable material has fallen in	Clean out crushing zone
	Breaker or armour plate fastenings have come loose and hammers graze against them	Check fastenings of plates in grate
Crushed product too coarse	Low rpm of mill rotor. Grate bars broken	Check grate bars. Reverse or interchange hammers
	Hammers or plates worn out	Replace worn out hammers or plates

Table 32

Screen Troubles and Their Remedies

Trouble	Cause	Remedy
	C-96A Eccentric-Drive Screen	
Vibration of screen frame or one of its sides exceeds 0.5 mm	Counterbalance weights out of adjustment	Readjust weights so that throw of frame does not exceed 0.5 mm
Excessive vibration of one end of screen and insufficient at other end	Tramp objects caught between vibrating and fixed frames	Remove tramp objects
	Failure or slackening of springs supporting body	Replace damaged springs, tighten bolts of slack springs
Reduced rpm of screen box	Belt slippage	Take up slack
	Accumulation of material in chutes, interfering with screen movement	Adjust tension, increase slope of chutes
Low screening efficiency	Material passes over screens too quickly	Check shaft rpm
	CM-13 Unbalanced-Throw Screen	
Knocking, uneven vibration	Failure of springs	Replace springs
Low screening efficiency	Material passes over screens too quickly	Check shaft rpm
Reduced vibrations of screen box	Belt slippage	Take up slack of belt
	Slackening of screen cloths	Adjust stretch of screen cloths
	Rings worn out	Replace rings

Table 33

Lowering of Machine Working Speed

Cause	Remedy
Low motor rpm	Check motor operation
Slippage of drive belts	Take up slack in belts by moving motor back or by means of the take-up
Excessive or nonuniform feed rate	Adjust feed rate to deliver rated amount of material to machine
Machine overloaded (clogged) with material	Clean out machine and readjust feed rate
Slow-down of working units due to feed or tramp material getting caught in clearances	Clean out machine; remove tramp material

CHAPTER SEVEN

ARRANGING THE WORKING PLACE

32. Machine Operator's Working Place

In regard to the operation of contractor's machinery, the working place is the site of installment of the machine and the area serviced by it. This area accommodates the machine, the machine attendants, the materials essential to normal operation of the machine and a certain part of the finished product.

Proper arrangement of the working place is an important factor for the productivity of the machine operator and machine attendants, for safe and continuous operation of the machine and for the quality of the finished products.

Rational arrangement of the working place involves proper installation of the machine in conformance with technological requirements, accident and fire prevention rules; uninterrupted supply of construction and operating materials, power, water and compressed air; availability of all necessary documentation at the working place; keeping near the machine only indispensable amounts of construction materials properly stored, sets of spares and tool kits; timely removal of finished products; presence at the working place of only the workers tending the machine, and observance by the operator of all instructions and plant regulations.

The state of the working place and labour conditions depend largely on the operator himself. A careful and resourceful worker will take part in equipping his working place and will demand that the management supply everything necessary to create good labour conditions.

Each machine should have on it all necessary documents, viz., certificate, operation instructions, repair log or chart and inventory of equipment, spares and tools.

To operate a machine properly and attain high productivity the technical characteristics and operation rules of the machine must be known.

The technical characteristics of the machine are given in its certificate, and the rules for its operation are described in a special instruction book.

The certificate states the name of the machine, the name of the plant that manufactured it, the year it was issued, its serial number and the number by which it is entered in the construction equipment list (inventory number).

The technical characteristics of the machine include its purpose, capacity, motor power rating, revolutions or strokes per minute of chief members, speed, principal dimensions, weight, construction of main mechanisms and gear train diagram.

The operating instruction book contains the technical characteristics of the machine; a general view of the machine; its gear train diagram and lubrication diagram; drawings of its main assemblies; a description of the machine and its operation; lubricating data, indicating the points and schedule of lubrication; grades of lubricants to be used; list of possible operating troubles and their remedies; instructions for installing the machine at its working site; rules for starting and stopping the machine, hints concerning control of its operation and operating rules.

Besides, operating instructions usually include safety and accident prevention rules relevant to operation of the machine in question. The repair log keeps a record of repairs made. The entries in this log show when and what kind of repairs were made on the machine and where they were done.

A set of spares for replacing rapid-wearing parts of the machine must be kept near the machine, as well as the required tools and operating materials.

The safety guards on the machine must meet safety engineering requirements and must always be in place and kept in good repair. No unnecessary parts or tools should be left lying around in the room or at the machine site. The machine room and the starting equipment boxes should be locked, with one key in the possession of the machine operator and another in the possession of the section mechanic.

Tools should be kept in good order in a box. Fuel and lubricants should be kept in covered containers in the amount permitted by the technical supervisor. Cans of fuel and lubricants should not be left standing close to the ma-

chine. There should be two covered steel boxes at the working place for clean and used wiping materials, respectively.

The technical supervisor should give instructions as to the quantity of these materials to be kept at the contractor's machine and where to keep them.

Order and cleanliness of the working place are the basic factors for efficient and safe operation.

33. Machine Operator's Duties

The operator of a contractor's machine is responsible for proper operation of the machine and its condition during work hours. He has no right to operate the machine unless he is well acquainted with its construction and the chief jobs accomplished by the machines in his section, and therefore, only qualified workers may be allowed to operate contractor's machinery.

During work hours the operator tends only one machine. He should take care that all the points of the operating instruction book are carried out and is held responsible for any breach of the rules listed in it. Such a breach of rules may result in failure of the machine or its elements, and in accidents.

Machine maintenance is one of the duties of the machine operator. This includes: cleaning, inspecting, lubricating the machine and its motor before starting, during operation and after operation in accordance with the machine operating instructions, and making running repairs together with the repairmen.

When starting or stopping the machine the operator must follow the rules given in the instruction book; the machine may be started only after the operator has made sure it is fully in working order.

Before starting or stopping the machine the operator gives a signal. If any trouble occurs in the machine or its motor that may cause a breakdown the operator must immediately stop the machine and notify the mechanic, repairman or electrician.

The operator must not attempt to deal with any trouble in the electrical parts of the machine, wiring or motor in the absence of the electrician.

The operator must not operate the machine unless he has written instructions on its operation in his possession; he is responsible for fulfilment of these instructions, because breach of them entails the same consequences as breach of the rules indicated in the certificate.

The operator must not divert his attention from tending the machine, nor allow outsiders at the working place, to say nothing of letting them operate the machine.

The machine must be operated strictly according to operating instructions.

Material should be fed to the conveyor belt, screen, elevator, screw conveyor, crusher, washing trommel, etc., only after the working parts of the machine have gathered normal speed. When operating belt conveyors, take care that the material covers the length of the belt in an even layer, filling its entire width, and that it does not spill or build up on the idlers and pulleys; the conveyor belt should not slip or come out of train; idlers should rotate without stopping.

Before stopping work cut off the feed, and stop the machine only when it is free from material. A number of safety rules should be observed during operation of the machine. The operator must know these rules and fulfil them.

Machine operation at the construction site is not only planned but accounted as well. This is necessary in order to know the amount of work done, to know how efficiently the machine is being used and to reveal the best workers at the construction site. For this reason the operator is required to fill out shift reports by which the performance of the machine is accounted.

The operator is responsible for the quality of the product put out by the machine and the amount of work done.

The operator sees to it that he is always adequately supplied with building and operating materials, spares and tools, that they are always in the right place, that finished products are removed and new batches of materials delivered on time, and informs his superiors of all trouble and lack of materials.

To keep the machine in shape and working productively, and to avoid injury to the men tending it the working place around it must be well arranged. It is the duty of the machine operator to keep his working place in good order.

CHAPTER EIGHT

SAFETY FIRST AND FIRE PREVENTION

34. Basic Safety Rules

Industrial safety rules are drawn up to prevent accidents. Observance of these rules ensures workers from accidents, safeguards their health and promotes high productivity.

Each trade in industry is covered by special safety instructions indicating the conditions necessary for safe work and the measures that must be taken to fulfil these conditions.

Every operator must master the safety instructions covering the operation of the machine he runs, and must also be instructed verbally by the leading mechanic before being put on the job.

Irrespective of the type and purpose of the machine, the following general safety rules must be observed.

The machine operator must be thoroughly acquainted with the working principle of the machines he is to run, the operating instructions of the machine and the safety rules. The operator must know how to control the machine, maintain it in fit condition and carry out minor routine repairs.

No operator should be permitted to run a machine unless he can produce certificates to the effect that he has passed the necessary qualification tests and a medical examination.

Machines that are to work for a long time at one place should be installed on and made fast to a strong foundation in such a way as to provide easy access to their parts.

Portable machines should be set on blocks or timbers so as to prevent them from vibrating or rocking and to hold them in place during operation.

Before starting up a machine that has just been installed or repaired it must be tested. First check to see that no foreign objects (tools, bolts, nuts, etc.) have been left on the machine or in its mechanisms.

Never install or remove drive belts, clean, repair or adjust machine units when they are running.

When the machine is not in operation, its starting equipment should be switched off and locked up, and its drive belts removed.

Never start a machine before making sure it is in working order.

Never operate a machine that is out of repair or adjustment.

Before starting up the machine, the operator must sound a signal, after which the workers tending the machine must be especially attentive.

Load the machine only after checking its operation during an idle run.

Transmissions (gear, chain, belt drives, etc.) should be arranged in places accessible for inspection and should be enclosed by strong and rigidly fixed housings or guards designed to make inspection and maintenance convenient.

Starting devices should be located so they are convenient for starting and stopping the unit.

When operated during the dark hours of the day, the machine and the working place should be well illuminated.

No outsiders should be allowed at the working place.

The operator has no right to entrust anybody with control of the machine except by the mechanic's permission.

The clothes worn by the worker while tending the machine must be buttoned up. Never take off or put on articles of clothing near an operating machine, as they may be caught by the moving parts. The clothes must never have hanging ends, or loose belts, etc. Approved coveralls and headgear should be worn.

A set of safety rules should be posted near each machine.

Besides the general safety rules, the following special rules should be observed during the operation of certain kinds of machines.

Conveyor belts must never be touched or taken up during operation. The conveyor frame must not be raised or lowered, and idlers that have stopped rotating must not be started up by hand.

Crushers should be furnished with special deflector shields over the feed opening to keep pieces of rock from flying out during operation. Never drag or pick out clogged

pieces of rock with the crusher working. No rock must remain in the crusher after it is stopped.

Special safety requirements should be observed during the operation of *electric motors.*

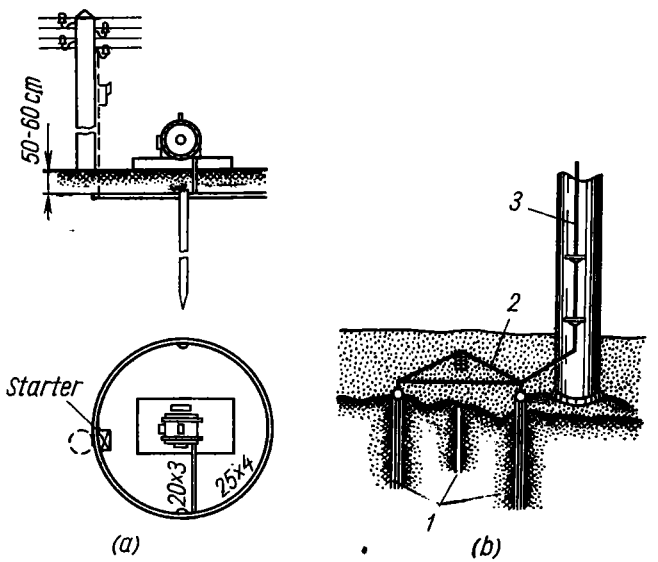


Fig. 161. Protective earthing:
(*a*) general view, (*b*) diagram; *1*—earth conductors, *2*, *3*—earth wiring

Electric shock may result from touching normally live parts or from touching metallic parts that have accidentally become live due to some fault.

The wiring of operating electrical equipment must be well insulated.

Parts of a unit that normally do not carry current but may accidentally become live should be earthed, i.e., should be connected to a suitable earthing network (Fig. 161).

The most commonly used earthing consists of electrodes which are steel pipes 25 to 50 mm in diameter driven into the ground to a depth of 2.5-3 m. All the earthing electrodes driven into the ground should be interconnected. Electric motor frames, rheostat enclosures, the metallic enclosures of all switchgear, etc., must always be earthed.

An interruption in power delivery or a considerable voltage drop in the main may cause a motor to stall or overheat and become a danger to the men working near it. To prevent this, motors should be provided with a no-voltage protective relay which may be incorporated in the starter and consists of a single-phase coil with a core connected to the switch contacts and a tripping spring. As long as the voltage in the main does not drop too low, the current passing through the coil permits the switch to remain in its "On" position. If the voltage drops too low the device may either trip a latch, or the force developed by the coil may become no longer sufficient to keep the starter closed. In either case the main contacts are thrown open by gravity or under the action of an opening spring to switch off the power.

Only authorized electricians have the right to send electrical equipment for repairs and to deal with trouble in the power main, wiring and electrical equipment.

Electric motors must not be repaired or cleaned during operation, except for cleaning of slip rings and test work which is carried out according to special rules.

Installment and repair of an earthing connection during motor operation are prohibited.

Motor starting equipment must be sectioned off by solid partitions. These partitions may be opened for inspection of the equipment only by authorized electricians.

The circuits of slip-ring induction motors running to the starting of field rheostats must be regarded as circuits of the same voltage as the supply.

During repairs, the motor must be disconnected from the main, the fuses removed, and the handle of its switch tied or locked in the "Open" position and a sign reading "Do not touch—men working" hung on it.

Circuit breakers and isolators (disconnecting switches) must be put into a position precluding any possibility of their being closed accidentally; for example, the handles of their operating mechanisms should be removed.

Never repair or adjust starting devices with any of their parts under voltage.

If when a motor is being replaced any current-carrying parts, even though insulated, remain accessible and may be touched accidentally, they must be sectioned with guards. Signs must be hung on the guards reading "Danger—do not

touch". Until the guards are put in place, a man should be stationed at the motor to give warning of danger if necessary. When a machine is being repaired, its motor should be disconnected from it. A sign should be hung on the motor switch handle, reading "Do not touch—men at work" and other measures should be taken to prevent the motor from being started by mistake.

An entry should be made in the repair log indicating the reason why the motor was taken out of operation and the name of the person on whose order it was done. The motor is put back into operation by order of the person responsible for the repair of the machine, a corresponding entry being made in the log.

Never cover motors which are in service with canvas hoods. Motors which are in service should be covered with a hood made of wood or metal.

35. Fire Prevention

Highly flammable materials (gasoline, kerosene, etc.) are often used at construction sites, and careless handling may result in fires. Fires may also be caused by careless handling of electrical units and by smoking where smoking is prohibited.

The machine operator must be thoroughly familiar with the general fire prevention rules and should know how to put out a fire if one occurs. The following fire fighting materials should be available at the machine: two fire extinguishers, a barrel of water, two pails, a fire hook, two boxes of sand (totalling not less than 0.15 cu m), a crow bar and an axe.

The fire extinguishers should be kept at the operator's working place. The operator must know how to use the fire extinguishers, and each extinguisher should have the rules for its use attached to it.

Different materials require different methods of extinguishing if they catch fire. Burning wood is extinguished with water; burning oil (crude or refined), kerosene and gasoline are extinguished by blanketing the flame and the spilled liquid with sand or with a sheet of canvas. Burning wood and liquid fuels are best extinguished with fire extinguishers.

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TO THE READER

Mir Publishers would be grateful for your comments on the content, translation and design of this book. We would also be pleased to receive any other suggestions you may wish to make.

Our address is: Mir Publishers, 2, Pervy Rizhsky Pereulok, Moscow, U.S.S.R.

Printed in the Union of Soviet Socialist Republics